Communication

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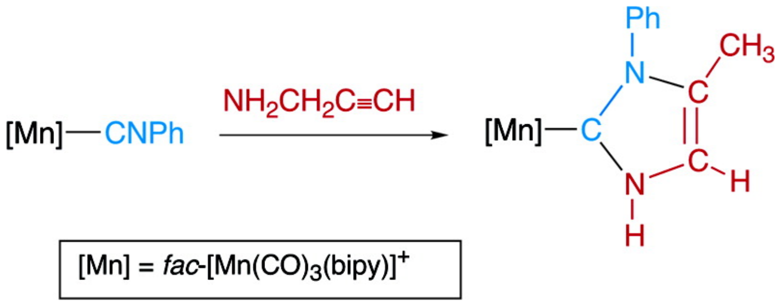

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Generation of N-Heterocyclic Carbenes by Metal-Mediated Coupling of Propargylamine and Isocyanides

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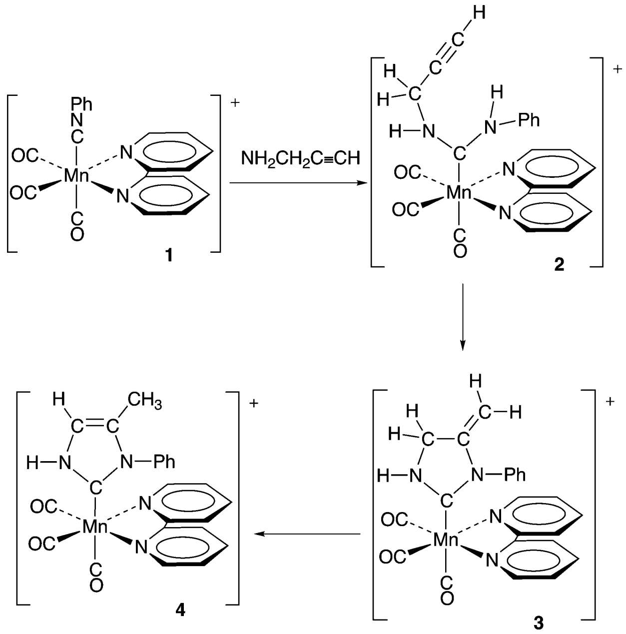
Nowadays, there is a great deal of interest in the chemistry of N-heterocyclic carbenes of imidazol-2-ylidene type (Arduengo's carbenes).[1] An important reason for the encouragement of this chemistry is the application of transition metal complexes bearing N-heterocyclic carbenes as ancillary ligands in homogeneous catalysis.[2] Methods for synthesizing these complexes mainly consist of direct reaction of either the stable Arduengo's carbene or the imidazolium salt with the appropriate metal fragment,[1] and eventually, via four-component condensation reactions with cyano transition metal complexes.[3] Here, we describe an unprecedented synthetic approach for the formation of unsymmetrically N-substituted Arduengo's carbenes and analogous N,O-heterocyclic carbenes that consists of the addition of propargylamine and propargylic alcohol, respectively, to coordinated isocyanide ligands.

Treatment of the cationic complex *fac*-$[Mn(CNPh)(CO)_3(bipy)]^+$ (**1**)[4] with propargylamine in refluxing THF cleanly affords the carbene complex **4** (Scheme 1), which was isolated as a yellow solid. The IR spectrum of **4** shows the disappearance of the νCN band of the isocyanide ligand, present at 2175 cm^{-1} in the starting complex **1**. ^1H NMR spectrum reveals the newly formed methyl group as a singlet at 1.76 ppm as well as the signal of the N−H proton at 9.84 ppm. The vinyl proton resonance appears at 6.94 ppm. In addition, the $^{13}C\{^1H\}$ NMR spectrum of **4** shows the carbene carbon atom resonance at 184.7 ppm (see Supporting Information for complete characterization data).

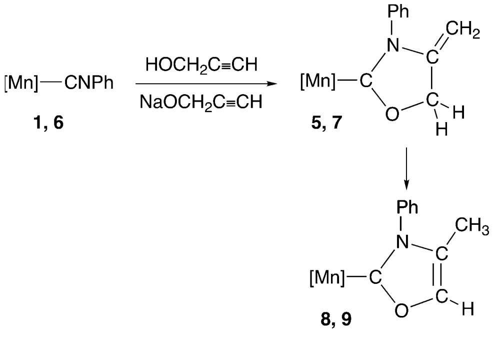
A likely mechanism for the formation of **4** is shown in Scheme 1. In a first step, nucleophilic attack of the amine to the isocyanide affords the acyclic diaminocarbene complex **2**. Then, an intramolecular hydroamination of the terminal alkyne would lead to the formation of the cyclic carbene **3**, which is finally transformed to **4** by a 1,3 proton shift from the endocyclic methylene group to the exocyclic one.

It should be noted that intramolecular cyclization of amino-functionalized isocyanides to obtain N-heterocyclic carbenes has been described in the literature.[5] Addition of haloamines to coordinated isocyanides to produce cyclic diaminocarbenes has also been reported.[6] However, to our knowledge, this is the first time that propargylamine is used in the synthesis of carbene complexes, and very interestingly, a cyclization process involving the alkyne group occurs, allowing the formation of N-heterocyclic carbenes of Arduengo class.

Scheme 1 . Postulated Mechanism for N-Heterocyclic Carbene Complex Formation



Scheme 2. Generation of Oxazol-2-ylidene Carbene Complexes (**1**, **5**, **8**: [Mn] = *fac*-$[Mn(CO)_3(bipy)]^+$; **6**, **7**, **9**: [Mn] = *fac*-$[Mn(CO)_3(dppm)]^+$)



The reaction above could be extended to propargylic alcohol, affording a similar result. Thus, the stirring of a THF solution of **1** with a mixture of $HOCH_2C\equiv CH$ and $NaOCH_2C\equiv CH$ for 10 h at room temperature yields complex **8** (Scheme 2), which contains a new N,O-heterocyclic carbene. In this case, the presence of the sodium alkoxide acting as a base catalyst, is essential for the reaction to take place. The ^1H NMR spectrum of **8** shows the methyl signal at 1.77 ppm. In the $^{13}C\{^1H\}$ NMR spectrum, the carbene carbon gives rise to a characteristic strongly low-field-shifted signal at 215.9 ppm. Fortunately, we have been able to isolate and characterize the intermediate carbene complex **5**, containing the carbon═carbon double bond in the exocyclic position, which supports the cyclization mechanism depicted in Scheme 1. **5** displays a very low-field signal for the carbene carbon atom (241.1 ppm) and clearly shows the methylene (5.14 ppm, triplet, 3 Hz) and vinylidene (4.51, quartet,

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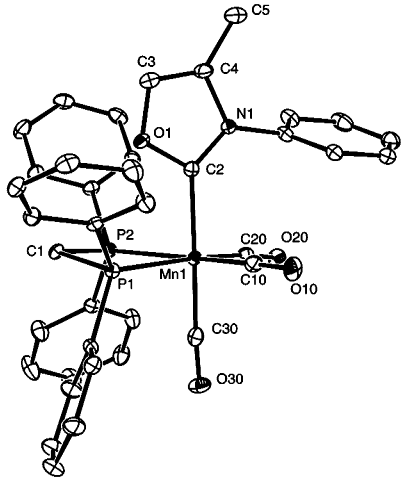


Figure 1. ORTEP diagram of the structure of the cationic complex **9**. Selected bond distances (Å) and angles (deg) are as follows: C2−Mn1 2.033(4), C2−O1 1.355(5), C2−N1 1.341(5), O1−C3 1.384(5), C3−C4 1.324(7), C4−N1 1.403(5), C4−C5 1.503(7); O1−C2−N1 105.2(3), C2−N1−C4 111.1(4), N1−C4−C3 105.4(4), C4−C3−O1 108.7(4), C3−O1−C2 109.5(3).

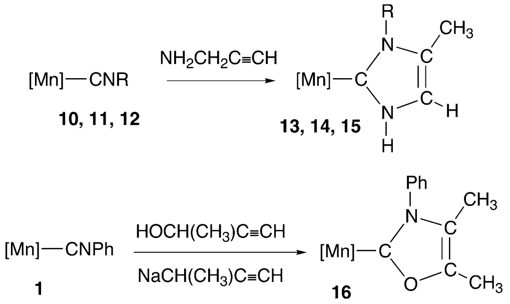
3 Hz; 3.99, quartet, 3 Hz) CH_2 protons in the NMR spectra. Contrary to imidazol-2-ylidene carbenes, free oxazol-2-ylidene carbenes are not isolable, being of special interest to the development of new reaction pathways for the synthesis of their transition metal complexes,[7] as that described herein. Related benzoxazol-2-ylidene carbene complexes can be prepared by intramolecular cyclization of 2-hydroxyphenyl isocyanide coordinated to transition metals.[8] However, this implies a multiple steps process, as free 2-hydroxyphenyl isocyanide is not stable and the hydroxy group must be protected before coordination.

On changing the bidentate ligand from bipy to a more electron-donor ligand, such as dppm, the electrophilicity of the coordinated isocyanide is reduced, so that no reaction was found between *fac*-$[Mn(CNPh)(CO)_3(dppm)]^+$ (**6**)[9] and propargylamine in the same conditions as those for **1**. Under more forcing conditions (very large excess of amine in refluxing toluene), deprotonation of the dppm ligand occurred instead of formation of the target carbene complex.[10]

Nevertheless, the reaction of **6** with propargylic alcohol in the presence of $NaOCH_2C{\equiv}CH$ gives rise to selective formation of the N,O-heterocyclic carbene complex **9** (Scheme 2). **9** shows spectroscopic data similar to those of **8**, especially the methyl signal at 1.72 ppm in the ^1H NMR spectrum that indicates that cyclization has taken place. It proved possible to obtain crystals of **9** suitable for an X-ray structure determination, which allowed us to confirm the proposed formulation for this complex (Figure 1). The different bond distances and angles within the carbene ligand (see Figure 1 caption) fall in the range observed for related benzoxazol-2-ylidene carbene complexes described in the literature.[11]

The experimental approach described herein could allow the synthesis of a great variety of N-heterocyclic carbenes, by selecting different isocyanide ligands as well as substituted propargylamines and propargylic alcohols. Some preliminary examples are represented in Scheme 3, which includes the heterocyclic carbenes derived from xylylisocyanide (**13**), 2,6-difluorophenylisocyanide (**14**), and benzylisocyanide (**15**), as well as that obtained when using the substituted propargylic alcohol 1-butyn-3-ol (**16**). These new compounds are easily characterized by the presence of the newly formed methyl group at 1.71, 1.83, 1.87, and 1.65 ppm, respectively.

Scheme 3. [Mn] = *fac*-$[Mn(CO)_3(bipy)]^+$ (**10**, **13**: R = xylyl; **11**, **14**: R = $C_6H_3F_2$; **12**, **15**: R = CH_2Ph)



Additionally, functionalization of the N−H residue of the carbene should lead to a variety of unsymmetrically N,N′-substituted carbenes. We are currently investigating all of these aspects as well as the reactivity of isocyanide complexes of metals other than manganese in order to synthesize a number of Arduengo's carbene complexes, especially of those metals with promising catalytic activity, such as palladium and ruthenium.

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Supporting Information Available: Experimental procedures and characterization data for new compounds (PDF), and crystallographic data for **9** (CIF). This material is available free of charge via the Internet at http://pubs.acs.org.

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