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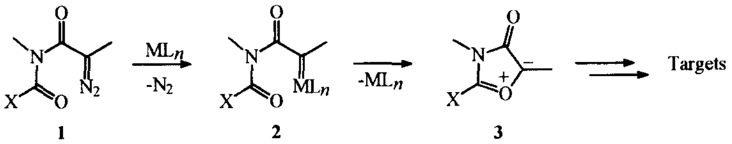
Ammonium Ylide Versus Carbonyl Ylide Formation in the Rhodium(II)-Catalyzed Decomposition of Diazoacetylureas. Generation and X-Ray Structure of a Stable Five-Membered N-Acyl Ammonium Ylide.

C. Oliver Kappe
Institute of Organic Chemistry, Karl-Franzens-University Graz, Heinrichstrasse 28, A-8010 Graz, Austria

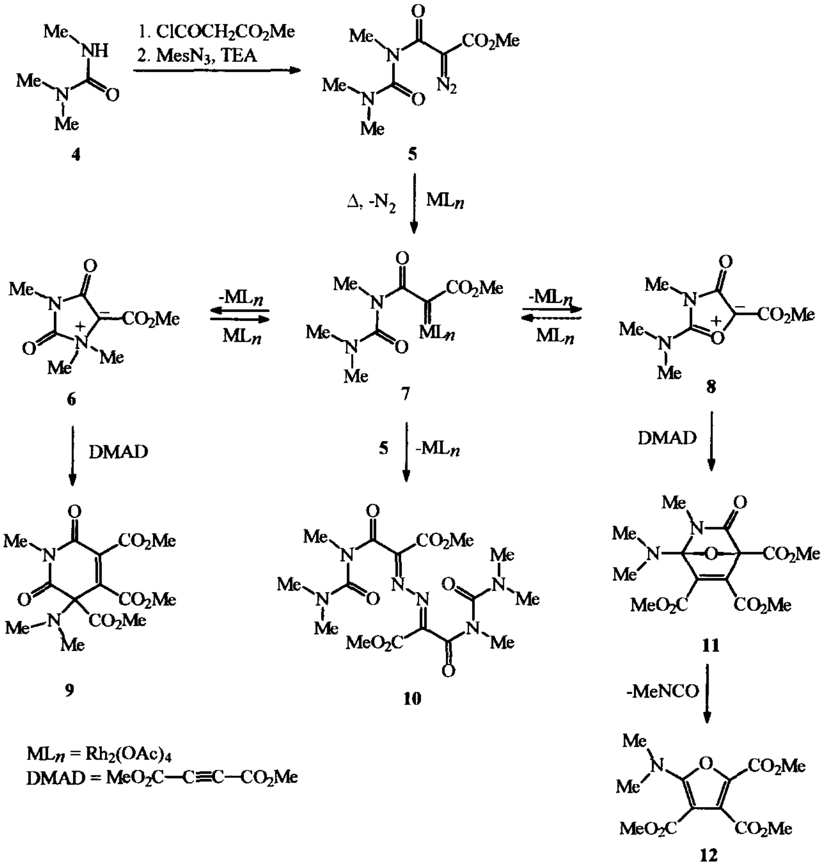
Abstract: The Rh(II)-catalyzed decomposition of diazoacetylurea **5** gives rise to carbenoid intermediate **7** which can either cyclize to ammonium ylide **6** or to the isomeric carbonyl ylide dipole **8**. In the presence of a rhodium catalyst, ammonium ylide **6** rearranges to carbonyl ylide **8** which undergoes 1,3-dipolar cycloaddition reaction with DMAD to give furan **12**. © 1997 Elsevier Science Ltd.

The transition metal-catalyzed decomposition of diazo compounds has found widespread use in organic synthesis.[1,2] The resulting metallo carbenoid intermediates are known to undergo a variety of synthetically useful transformations such as cyclopropanation, X-H insertion or ylide formation.[1,2] In many cases the chemo- and regioselectivity of these reactions can be influenced with impressive degree of control by the nature of the catalyst.[3] The transition metal-catalyzed decomposition of diazo imides of type **1** produces a cyclic carbonyl ylide dipole, *i.e.* isomünchnone **3**, by intramolecular trapping of the initially formed metallo carbenoid by the lone pair of electrons on the neighboring carbonyl group.[4] Due to the inherent instability of such 1,3-dipolar systems, these mesoionics are usually generated *in situ* in the presence of suitable dipolarophiles.[4] In recent years, isomünchnones **3** have attracted a considerable amount of attention and have emerged as valuable intermediates for the synthesis of structurally complex target molecules and natural products.[4-6]



In the context of our efforts to generate persistently stable isomünchnones as synthons we have investigated the rhodium-catalyzed decomposition of diazo imides bearing an additional amino substituent at the carbonyl functionality (**1**, X = NR_2). The resulting "*aminoisomünchnones*" of type **3** (X = NR_2) should be particularly stable due to the electron-donating properties of the 2-amino substituent.

As a suitable model system we have chosen diazoacetylurea **5** which could readily be prepared from trimethylurea (**4**) by sequential N-malonylacylation[6] and diazo transfer reaction[7] in 72% combined yield (mp 46-50 °C).[8] When diazo compound **5** was heated at reflux in dry benzene in the presence of a catalytic amount of $Rh_2(OAc)_4$, a colorless solid precipitated from the reaction mixture. Surprisingly, this material was identified as ammonium ylide **6** (mp 199-201 °C, 39% yield) by X-ray analysis (see below) and not as the anticipated isomeric isomünchnone dipole **8**. Chromatographic work-up of the mother liquor gave azine **10** (mp 154-156 °C, 32%)[9] as the only other isolable product (the crude ^{1}H-NMR spectrum did not show any signals due to dipole **8**). Employing a high dilution protocol, *i.e.* dropwise addition of a solution of **5** in toluene to refluxing toluene containing the catalyst, allowed the isolation of ylide **6** in 65-70% optimized yield with only small amounts of azine **10** (5-10%) being formed. When the reaction was repeated in the presence of 2 equiv of dimethyl acetylenedicarboxylate (DMAD), 2-aminofuran **12** (mp 107-109 °C, 25%) and adduct **9** (mp 156-158 °C, 18%) were formed as the two major new products along with ylide **6** (28%). The formation of furan **12** strongly suggests the generation of isomünchnone dipole **8** as an intermediate in this process. 1,3-Dipolar cycloaddition of DMAD with isomünchnone **8**, followed by extrusion of methyl isocyanate from the primary cycloadduct **11** produces furan **12**, a reaction sequence well established in isomünchnone chemistry.[4] Adduct **9** on the other hand arises from the thermal addition of DMAD to ylide **6** which was confirmed by an independent experiment in which **6** was treated with DMAD in refluxing toluene (2h, 61% isolated yield, the structure of **9** was established by an X-ray analysis).[10] Importantly, when the reaction of DMAD with ammonium ylide **6** was carried out *in the presence of $Rh_2(OAc)_4$*, furan **12** was formed in small but significant amounts (10-15%), along with the thermal adduct **9** (no trace of **12** could be detected in the absence of the rhodium catalyst). These results suggest that in the presence of a transition metal catalyst the formation of ammonium ylide **6** is reversible, and that **6** rearranges to carbonyl ylide **8** *via* the carbenoid intermediate 7. Due to the 1,3-dipolar character of ylide **8** this mesoionic species then rapidly cycloadds to DMAD, ultimately giving furan **12**. The reversibility of ylide formations from metallo carbenoids has been reported.[11]



The solid-state structure of the persistently stable N-acyl ammonium ylide **6** was determined by an X-ray analysis (Figure 1, Table 1).[10] The five-membered heterocyclic ring is nearly planar, the relatively short C5-C6 bond length of 1.403 Å indicates a strong contribution from the resonance structure **6b**. Whereas the C10-N8 bond length of 1.332 Å is typical for an amide C-N bond, the C6-N8 distance of 1.453 Å shows little amide-type character and again indicates that this novel type of ammonium ylide[12] is best described by the 2,3-dihydro-1*H*-imidazol-1-ium-4-olate resonance structure **6b**.

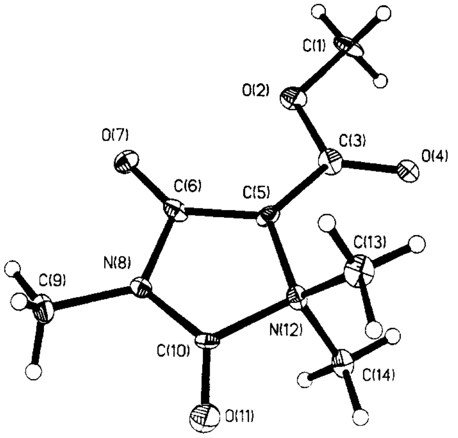
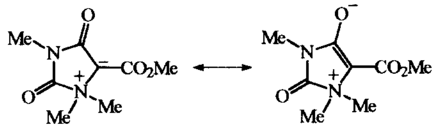


Figure 1. X-ray structure of ylide **6** at 95K.

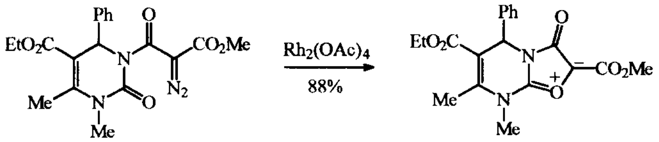
Table 1: Bond Lengths [Å] in Ylide **6**.

O11-C10	1.207(3)	N8-C10	1.332(3)
N8-C9	1.462(3)	N8-C6	1.453(3)
O4-C3	1.224(3)	N12-C14	1.469(9)
N12-C5	1.479(3)	N12-C10	1.524(3)
N12-C13	1.547(9)	O2-C3	1.360(3)
O2-C1	1.446(3)	O7-C6	1.225(3)
C5-C6	1.403(3)	C5-C3	1.424(3)



6a **6b**

It appears that the reactivity pattern and thus the product distribution (ammonium- versus carbonyl ylide formation) in the decomposition of diazo compound **5** is a direct consequence of the conformational flexibility of the metallo carbenoid intermediate **7**. The highly electrophilic carbenoid center can either attack the lone pair of electrons on the amide nitrogen (ammonium ylide formation) or the lone pair of electrons on the carbonyl oxygen (carbonyl ylide formation). In order to restrict the conformational freedom in such carbenoids we have prepared cyclic diazoacetylurea **13**, readily available from the known N3-H derivative,[13] by N3-malonylacylation followed by diazo transfer reaction (see above). As anticipated, the $Rh_2(OAc)_4$-catalyzed decomposition of **13** in refluxing benzene produced isomünchnone **14** (mp 235 °C) as a colorless solid in high yield. This "*aminoisomünchnone*" proved to be remarkably stable and could even be recrystallized from methanol.[14] A crystalline sample of **14** could be kept in the open air for two months without any sign of decomposition (^{1}H-NMR). Despite its apparent stability, isomünchnone **14** retained its 1,3-dipolar character and smoothly reacted with dipolarophiles such as N-methylmaleimide at room temperature to give the corresponding 1,3-dipolar cycloadducts in high yields.



13 **14**

In summary, we have shown that the rhodium-catalyzed decomposition of diazoacetylureas can lead to both ammonium ylides and/or carbonyl ylides depending on the conformational flexibility of the carbenoid intermediates and reaction conditions employed. At the present time the experimental evidence suggests that the formation of these ylides is reversible and that such ylides may be interconverted in the presence of transition metal catalysts. Further work will be devoted to selectively control the chemoselectivity in these processes (N- versus O-ylide formation) by variation of the transition metal catalyst.

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