

TRANSITION METAL CATALYZED 1-3-DIPOLAR CYCLOADDITION
OF CARBETHOXYSARBENE TO ACRYLONITRILE *

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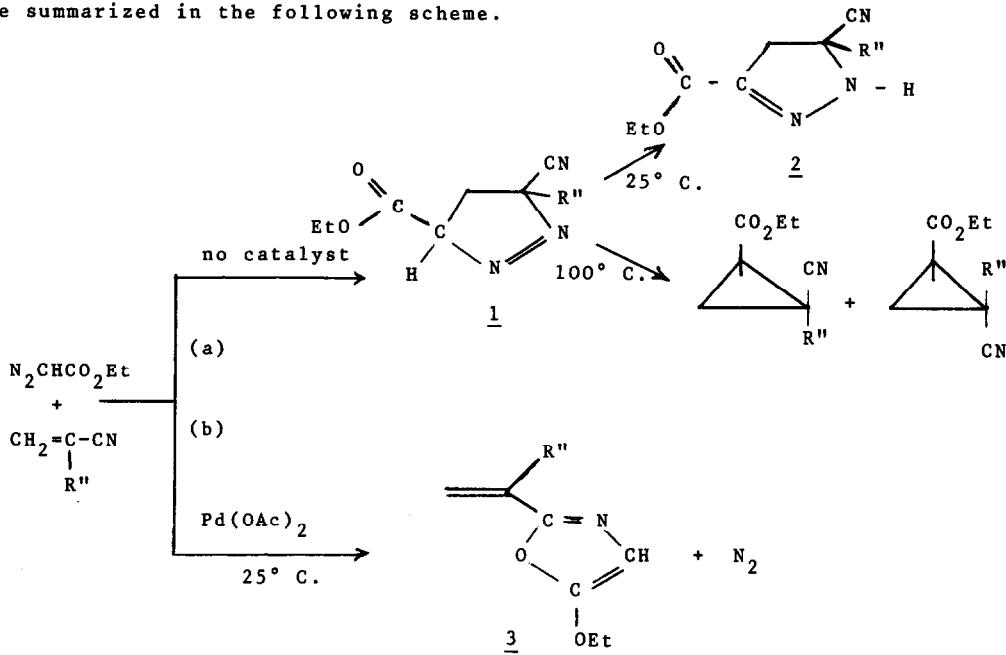
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Ketocarbene are known to undergo spontaneously Wolff rearrangement rather than intermolecular reactions; in the presence of copper catalysts however, they react as a bivalent reagent either as a carbenic species (leading e.g. to cyclopropanation of olefins) (1), acetylenes (2), ketene (3), acetone (4), carbon disulfide, phenyl isothiocyanate (5) or nitriles (6,7). With nitriles, oxazoles are generally formed but yields are rather poor when the ketocarbene is produced either by photolysis or by thermolysis of diazocompounds and are only slightly improved by use of copper catalysts (8). Moreover, the extension of these results to polyfunctional nitriles failed, up to now, because of the low reactivity of the nitrile group relative to other functions such as olefinic groups : for example, only Δ^2 pyrazoline 2 is obtained (65 % yield) when acrylonitrile is allowed to react with ethyl diazoacetate at room temperature without any catalyst (9). (The correct structure of 2, different from those reported in the literature, has been ascertained by i.r. and n.m.r. spectroscopy (10)). In contrast, we have found that, at temperatures higher than 100° C., cyclopropanation takes place quantitatively. These interesting observations may be interpreted by a prior formation of the Δ^1 pyrazoline 1 which is readily isomerised to its Δ^2 isomer at room temperature, whereas direct decomposition to cyclopropane derivatives occurs at higher temperature (Δ^2 pyrazoline never decomposes to cyclopropanes).

In a recent investigation of the influence of transition metal complexes on the selectivity of typical reactions of carbene, we have already shown that cyclopropanation of olefins (11), as well as insertion in polar X-H bonds (X = O, S, NH) were very efficiently catalysed by palladium and rhodium complexes (12).

* For the previous papers in the series, see references 11 and 12.

We have consequently examined the influence of these transition metal catalysts on the reaction of diazoacetates and nitriles, and we have put in evidence a definite effect of palladium(II) acetate on reaction (b) (palladium chloride and cyanide are much less efficient catalysts). Acetonitrile, benzonitrile and benzylcyanide react at room temperature to give oxazoles in 22, 28 and 20 % yield respectively. However, the most interesting behaviour, not observed with usual copper catalysts, is obtained with acrylonitrile ($R'' = H$) and methacrylonitrile ($R'' = CH_3$) which form the corresponding 2-vinyl-5-ethoxy-oxazoles 3 (reaction b) with complete exclusion of pyrazoline 2. The results are summarized in the following scheme.



In a typical run for synthetical purpose, ethyl diazoacetate (0,05 m) is added slowly (over 24 hrs) to a well-stirred solution of $Pd(OAc)_2$ (0,001 m) in nitrile (0,5 m). Evaporation of the solvent and distillation afford the oxazole in 30 % yield.

3 ($R'' = H$ and CH_3) have been identified by elemental analysis and spectroscopic data. In particular, 1H NMR spectra of 3 ($R'' = H$) in CCl_4 shows a typical ABC styrene-type system with three quartets centered respectively at $\delta = 5.32$, 5.79 and 6.30 ppm in addition to the triplet ($\delta = 1.35$) and the quartet ($\delta = 4.04$) of the ethoxy group and the singlet ($\delta = 5.93$) corresponding to the methine proton of the cycle.

In the same solvent, 3 ($R'' = CH_3$) exhibits an AB system centered at 5.08 and 5.57 ppm in addition to a multiplet at 1.99 (2 H.), a triplet at 1.35 (3 H.), a quartet at 4.02 (2 H.) and a singlet at 5.92 (1 H.).

The polymerization of these two novel oxazoles, which are not accessible by other straightforward methods, is presently studied in our laboratory.

From the reaction mixture, ethyl maleate, ethyl fumarate and polyketocarbene were also identified.

This last well-characterized polymeric material represents an important part of the initial diazoacetate. The other reactions occur only in the presence of the catalyst, whereas pyrazoline 2 is the sole product formed in its absence. It is characteristic of a competitive coordination reaction that the yields in 2 drop considerably when catalyst concentration increases, whereas the yields in oxazoles increase progressively. Less palladium acetate is needed with methacrylonitrile than with acrylonitrile to get the best yield in oxazole; on the other hand, in the absence of any catalyst, the kinetics of the reaction indicate a much greater rate for the formation of 2 in the case of ($R'' = H$) than when ($R'' = CH_3$). The difference between acrylonitrile and methacrylonitrile may therefore be interpreted as the result of the greater sensitivity to steric hindrance in the pyrazoline reaction than in the catalytic steps leading to the oxazoles (13).

All of these observations fit with a mechanism involving the easy decomposition of the diazocompound through coordination on palladium, with formation of an intermediate coordinated ketocarbene undergoing further rearrangements. Such a coordinated ketocarbene would be responsible for the formation of polyketocarbene, ethyl maleate and fumarate as well as of oxazole in the catalytic process.

It is also significant that the selectivity in oxazole formation is notably improved by a slow addition of diazoacetate to the nitrile (see preparative procedure) : this is a good indication that the ratio diazoester/catalyst must be kept as close as possible to stoichiometry in order to avoid the formation of 2 by the uncatalysed reaction involving the free diazocompound. Moreover, the formation of polymers is also disfavoured as expected.

Some activation of the nitrile group, through coordination with the metal, contributes most probably to the observed selectivity (14).

Preliminary attempts to isolate the complexes led to precipitation of the metal, whereas the formation of by-products prevent any more detailed mechanistic approach of the reaction.

However, these results stress again the usefulness of coordination catalysis in fine organic synthesis.

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