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Copper(II) Catalyzed Cyclization of Azidoalkadienylquinones. Stereoselective Formation of Dihydropyrroloindoloquinones and the Related Quinolinoquinone#

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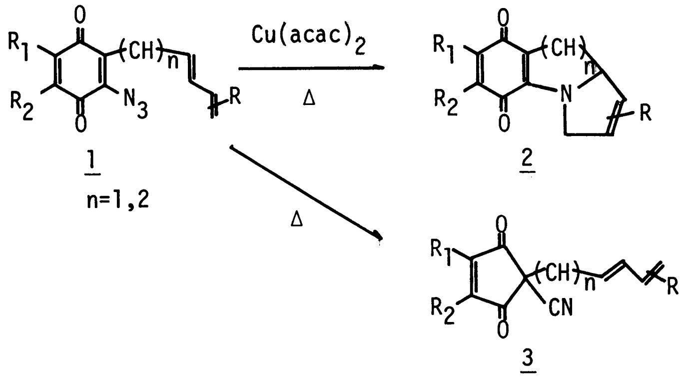
Copper (II) salt catalyzed reaction of 2-azido-1,4-quinones with a conjugated alkadienyl side chain stereoselectively gave dihydropyrroloindoloquinones or dihydropyrroloquinolinoquinones, both of which are hardly obtained by uncatalyzed pyrolyses or photochemical reactions.

Organic azides have been used as conventional starting materials in synthesis of nitrogen heterocycles,1) such as aziridines,2) pyrroles,3) indoloquinones,4) and pyrrolizidine alkaloids.5) Usually, thermal decomposition conditions are not applicable for the preparation of rather unstable nitrogen heterocycles and result in the less product selectivity in many cases. Since catalytic decomposition of the azides may be conducted at lower temperature, on the other hand, this method will be a promising alternative in the nitrogen heterocycle synthesis. However, only a limited number of examples of metal catalyzed thermal decompositions has been reported6) compared with those of diazo compounds.7)

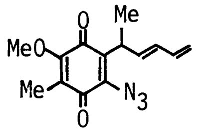
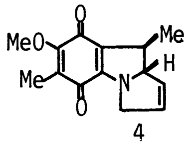
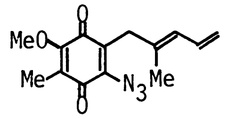
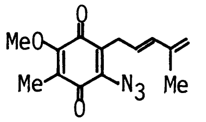
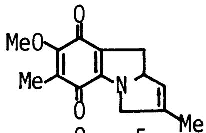
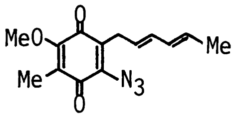
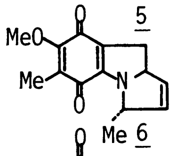
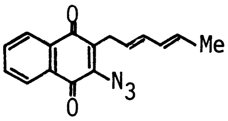
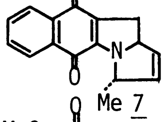
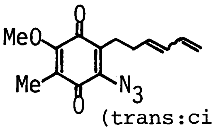
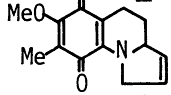
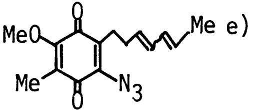
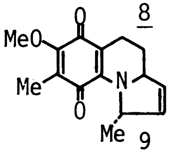
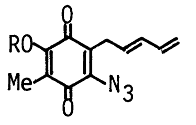
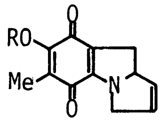
Previously, we reported the efficient intramolecular cyclization of 2-azido-3-(2',4'-pentadienyl)-1,4-quinones to 3*H*-pyrrolo[1,2-a]indole-5,8-dione in the presence of copper powder.8) Recently, we realized that Cu (II) salts, especially Cu(acac)$_2$, possessed the equivalent catalytic activity. In this report, we will show the generality and stereoselectivity of this cyclization.



First, to find an optimum catalyst we surveyed various metal salts ML$_n$,9) and Cu(acac)$_2$ showed the best catalytic activity. The reaction of the azidoquinones (1) with several substituted 2,4-pentadienyl or 3.5-hexadienyl side chains were conducted. Without a copper catalyst, all reactions afforded the corresponding ring contracted products such as 3

#Dedicated to Professor Teruaki Mukaiyama on the occasion of his 60th birthday.

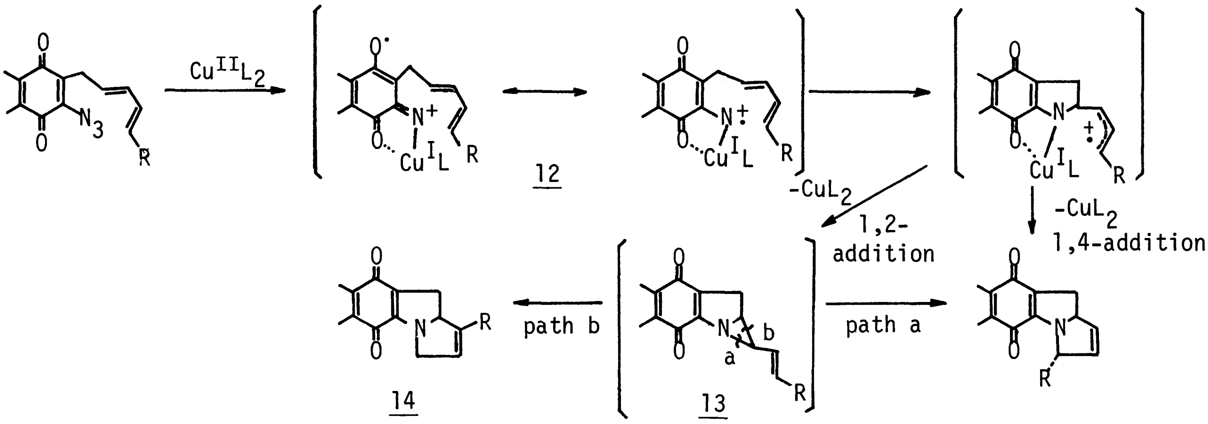
Table 1. $Cu(acac)_2$ Catalyzed Decomposition of Azidoquinones[a]

Entry	Azidoquinone[b]	Concentration [azidoquinone]/ M	Product[c]	Isolated yield/ %
1		0.01	 4	27
2		0.005		16
3		0.005	-	0[d]
4		0.005	 5	48
5		0.01	 6	22
6		0.01	 7	41
7	 (trans:cis=50:50)	0.01	 8	21
8	 ($\Delta^{3'}$,$\Delta^{5'}$;trans,trans:cis,trans=56:44)	0.086	 9	21
				
9	10a R=t-BuMe$_2$Si	0.005	11a R=t-BuMe$_2$Si	35
10	10b R=Ac	0.005	11b R=Ac	8
11	10c R=OH	0.01	11c R=OH	0[f]

[a] All reactions were performed under standard conditions; a dry benzene solution of an azidoquinone (0.3 mmol) and $Cu(acac)_2$ (0.6 mmol) were refluxed under nitrogen until the starting quinone disappeared. [b] Stereochemistry of the conjugated double bond in the azidoquinone was assigned to be trans or trans, trans configurations except noted. [c] Satisfactory ^{1}H-NMR, IR, and mass spectral data were obtained. The stereochemistry was confirmed by means of 400 MHz ^{1}H-NMR. [d] A complex mixture was obtained. [e] The $\Delta^{5'}$-cis isomer was not obtained. [f] A ring contracted product, 1-cyano-3-hydroxy-4-methyl-1-(2',4'-pentadienyl)-3-cyclopentene-2,5-dione, was obtained in 20% yield.

instead of the expected cyclized ones in the refluxed benzene.[10)] Addition of the catalytic amount (0.1 equiv.) of Cu(acac)$_2$ gave the cyclized product (2), and the best yield was obtained when the two equivalents of Cu(acac)$_2$ to the azidoquinone was used. The results under the optimum conditions are shown in Table 1. The cyclization proceeded in high stereoselectivity. The 1'-methyl derivative afforded selectively the corresponding β-isomer (4) (entry 1). The stereochemistry at the C-9 position was determined by the coupling constant $J_{9\alpha-9a}$=5.2 Hz, in comparison with those of the unsubstituted compounds, $J_{9\alpha-9a}$=6.9 Hz, $J_{9\beta-9a}$=11.5 Hz. trans,trans-2',4'-Hexadienyl derivatives also gave the corresponding cyclized products (6 and 7) with the α-Me configuration in a stereoselective manner (entries 5 and 6).[11)] The methyl substituent on the side chain affected intensively the product yield. In entry 3, only the complexed mixture was obtained instead of the cyclized product expected. 2-Azido-3-(3',5'-hexadienyl)-1,4-benzoquinones showed the similar cyclization reactions to afford the double cyclized products (8 and 9, entries 7 and 8).[11)]

In the analogy with the metal carbenoid chemistry, the present reaction can be explained in terms of the copper-nitrenium ion complex as shown in the following scheme. The copper (II) salt would form the intermediate copper (I)-nitrenium ion complex, which can be stabilized both by the delocalization of the unpaired electron over the quinone ring and by the bidentative coordination of the copper (I) ion with the quinone carbonyl group at the vicinal position. The presence of the former effect is supported by the avoidance of the cyclized product formation in the copper catalyzed reaction of 5-hydroxy derivative (10c), in which the copper ion can preferentially coordinate to the oxygen functionalities at the 4 and 5 positions. The elimination of the copper (II) ion and the successive intramolecular cyclization give the final products. It is unclear that the final cyclization occurs either by the 1,2-addition/sigmatropic rearrangement or by the direct 1,4-addition. Even if the vinyl aziridine (13) was formed as an intermediate,[12)] the ring cleavage of the aziridine could not occur via the path b, because this pathway might give the rearranged product of the terminal vinyl portion.[13)]



Scheme 1.

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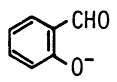
9) The following metal salts were examined for this cyclization. M(acac)$_2$; M= V(III), V(V)O, Cr(III), Mn(II), Mn(III), Fe(III), Co(II), Co(III), Ni(II), Cu(II), Zn(II). Cu(I)L ; L=Cl, Br, 1/2O. CN, OTf. Cu(II)L$_n$; L$_n$= tetraphenylporphyrin,



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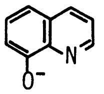

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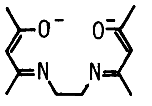

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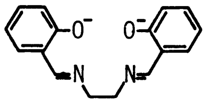

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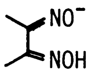

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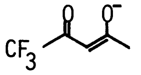

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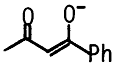

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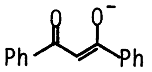

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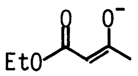

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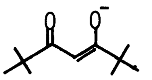

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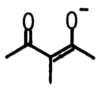

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10) W. Weyler, Jr., D. S. Pearce, and H. W. Moore, J. Am. Chem. Soc., 95, 2603 (1973).

11) The stereochemistry of the C-3 position of 6, 7, and 9 was determined by the CF_3CO_2H-induced ^{1}H-NMR shift values in comparison with those of the C-3 unsubstituted compounds.

12) Rearrangement of vinylaziridines to dihydropyrrole requires higher temperature, see Ref. 5.

13) Ref. 5 ; Bond cleavage of 2-vinylaziridines both at the C-C bond and at the C-N bond in their thermal rearrangement is reported to occur.

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