CYCLOADDITION REACTIONS OF PYRIDINES

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Abstract - Examples of cycloaddition reactions of pyridines and related compounds, as well as pyridinium N-methylides and pyridinium N-imino-ylides are reported.

Among enormous number of cycloaddition reactions - a powerful synthetic method in chemistry - those performed on azaromatic compounds are of special interest, providing route to new classes of heterocycles. This topic is included into reviews 1-9; the present paper is dealing with cycloaddition reactions of pyridine and related compounds.

Cycloaddition reactions of pyridines are classified into 3 groups:
1. Cycloadditions of pyridines
2. Cycloadditions and intramolecular cyclizations of pyridinium N-methylides
3. Cycloadditions and intramolecular cyclizations of pyridinium N-imino-ylides

1. Cycloadditions of pyridines

Burger et al. in the series of investigations of bis-trifluoromethyloxazaphospholine 1 as the 1,3-dipole precursor10, examined the direct imidazoannelation of heterocycles11. When the thermal decomposition of 1 was carried out in N-heterocycles such as pyridines or quinolines, the 1:1 adducts were obtained. In the reaction of pyrazine with 1, also the 1:2 adduct 2 was isolated.

$$\text{1} \quad \text{at 140^°, 24h}$$
$$\text{or 30-40^°, 7d}$$

R = tBu, C_6H_5, p-Me-C_6H_4, p-Cl-C_6H_4 etc.

$$\text{*d = days}$$
The reaction of 1,3,5-triazine with aromatic nitrile oxides was reported by Kurabayashi and Grundmann\textsuperscript{12}. The resulting 3-substituted 1,2,4-oxadiazoles\textsuperscript{2} are obtained in fair yields only when BF\textsubscript{3} is added.

Cycloaddition reactions of 2-substituted pyridines and quinolines were studied by Acheson\textsuperscript{13}. 2-Pyridylacetone with DMAD\textsuperscript{x} in MeOH-MeOH gives 4; 2-quinolylacetone however, under similar conditions yields the 1:2 molar cycloadduct\textsuperscript{2};\textsuperscript{13,14}

\textsuperscript{x}DMAD = dimethyl acetylenedicarboxylate; E=COOMe
The reaction of methyl pyridyl-2-acetate with DMAD in MeCN-MeOH affords 6 and 7, while in the case of ethyl quinoline-2-acetate the 1:2 molar adducts, cyclobutapyroles 8 and 9 were obtained:
Upon treatment with DMAD yielded pyridoazepines:\(^{14}\)

\[
\begin{align*}
\text{DMAD} & \quad \text{in dry ether, } 0^\circ \\
\text{R} = \text{Me, COMe, COC}_6\text{H}_5
\end{align*}
\]

With DMAD at room temperature gave the quinolizines \(^{12}\) and \(^{13}\), while at higher temperature \(^{12}\) and the indolizine \(^{14}\) were formed.\(^{14}\)

3-Methylpyridine with acetylenic ketone \(^{15}\) produced the adduct of the novel type \(^{16}\), which could be formed as follows:

Quinoline in a similar reaction afforded \(^{17}\).\(^{14}\)
Sakamoto et al. \(^{16}\) examined the reaction of 2-styrylpyridine and 2-styrylquinoline with diphenylketene \(^{18}\) yielding 1:2 molar cycloadducts \(19a\) and \(19b\):

\[
\begin{align*}
\text{Ar-CH}=\text{CH-C}_6\text{H}_5 & \quad \xrightarrow{\text{C}=\text{C}=\text{O}} \quad \text{Ar} \quad \text{C}_6\text{H}_5 \\
\text{in xylene, reflux, 10h} & \quad \text{in toluene, reflux} \\
\end{align*}
\]

\( \text{Ar} = 2\text{-pyridyl, 2-quinolyl} \)

On the other hand, 6-styrylphenanthridine reacted with \(18\) to give 1:2 and 1:1 adducts \(20\) and \(21\):

The cycloaddition of substituted pyridines \(22\) with phenyl isocyanate and diphenyl ketene was described by Bödeker et al. \(^{17,18}\). In the reaction of \(22\) with phenyl isocyanate the following cycloadducts were formed:

Treatment of 1-(3-methoxy-2-nitrobenzyl) isoquinoline \(23\) with ethylene oxide in acetic acid yielded stable 10b-substituted oxazoloisoquinoline \(24\) :
When quinoline was treated with ethylene oxide in AcOH, the novel labile oxazoloquinoline 25 was obtained.

![Chemical structure](image)

1,3-Dipolar cycloaddition reactions of 3-substituted and 3,4-disubstituted quinoline N-oxides were studied by Hamana et al.\textsuperscript{20} in order to investigate the effect of substituents on the reactivity of their N-O groups. It was shown that the reactivity was enhanced as compared with that of quinoline N-oxide itself.

Among the examined reactions were following: 3-bromoquinoline N-oxide 26, on treatment with DMAD, phenyl isocyanate or 1-morpholinocyclohexene, gives N-ylide 27, oxazoloquinoline 28, and 2,3-disubstituted quinoline 29, respectively.
Abramovitch investigated reactions of quinoline N-oxides with activated acetylenes and compared the results with those for pyridine N-oxides\textsuperscript{21-27}. When 4-chloroquinoline N-oxide was heated with ethyl phenylpropionate in boiling toluene, the following products were formed\textsuperscript{28}:

\[
\begin{align*}
\text{Cl} & \quad \text{H}_2\text{C=COOEt} \\
\begin{array}{c}
\text{in} \\
\text{toluene} \\
\text{reflux}
\end{array} & \quad \begin{array}{c}
\text{O} \\
\text{C}_6\text{H}_5 \\
\text{Cl}
\end{array} & \quad \begin{array}{c}
\text{COOEt} \\
\text{C}_6\text{H}_5 \\
\text{N} \\
\text{+}
\end{array} \\
\text{6.2\%} & \quad \text{N} & \quad \text{Cl} & \quad \text{COOEt} \\
\text{1.7\%} & \quad \text{H} & \quad \text{CH}_3 & \quad \text{10\%}
\end{align*}
\]

However, when α-picoline N-oxide reacted with methyl phenylpropionate, only 20 was obtained, and no cycloadduct could be detected in the reaction mixture\textsuperscript{29}.

Uchida reported the reaction of 2-piperidinecarboxylic acid and dibenzoylacetylene in the presence of Ac\textsubscript{2}O, producing via the 1,3-dipolar intermediate 21 the N-bridged lactone 22, and 23. The thermal decomposition of 22 yielded 23, which upon treatment with hydrazine hydrate gave tetrahydropyridazinoindolizine 34. In a similar way reacted other dipolarophiles such as DMAD, p-benzoquinone, 1,4-naphthoquinone etc. The above reaction provides a useful route to indolizines 30.
Among reactions which do not proceed at the N atom, the following ones can be mentioned.

1,3-Dipolar cycloaddition of 1,2-dihydropyridines with cyanogen azide affords diazabicyclohept-4-enes:

\[
\begin{align*}
N\text{-Methylisoquinolone} & \quad \text{reacts with dichlorocarbene to give 1:1 adduct 25, which}\nonumber \\
& \quad \text{refluxed in pyridine/H}_2\text{O yielded exclusively E-3-formylmethine-2-methylisoindole-}
onumber \\
& \quad \text{none 36. 32-34 The E stereochemistry was established by its photochemical transforma-}
onumber \\
& \quad \text{tion into the Z-isomer.}
\end{align*}
\]

The adduct 25 upon treatment with alcohols yielded 2-benzazepinone derivatives, e.g.:

\[
\begin{align*}
25 & \quad \text{undergoes subsequent cycloaddition to DMAD forming the intermediate 40, which aromatizes into 41. This undergoes Michael-}
onumber \\
& \quad \text{type addition with DMAD to give 42. 35}
\end{align*}
\]
On the other hand, with methyl propiolate the electrophilic attack at C-3 takes place, no carboxamide elimination occurs and the reaction results in tetrahydroazocine 43, thus providing a new route to this class of heterocycles:

Some 1,2-dihydropyridines behave as enamines, in the reaction with DMAD they yield primary cyclobuta[b]pyridines, which ring open to give azocines 36, 37, while a number of 1,4-dihydropyridines afford stable cyclobuta[b]pyridines, which do not ring open 38-40.

44 upon treatment with DMAD yields 45 together with 46. The reaction may be explained by vinyllogous enaminc character of 3,4 double bond of 44; the four-membered ring is formed, and subsequent electrophilic attack by another acetylene molecule at position 5, followed by amide elimination leads to 45 41.

A successive Diels-Alder addition and retrogression gives rise to the dimethyl phthalate derivative 46 41.
The reaction of 47 with DMAD proceeds as follows:

\[
\begin{align*}
\text{C} & \text{d} & \text{Me} & \text{E} \\
\text{N} & \text{R} & \text{Me} & \text{E}
\end{align*}
\]

The reaction of 1,4-dihydropyridines with DMAD gives rise to cyclobutapyridines, e.g.

\[
\text{H} \quad \text{R}^2 \quad \text{R}^3
\]

Matsumura reported the reaction of an electron deficient 50 with electron rich olefins. The reaction yields first a 1:1 molar adduct 51, which in the subsequent cycloaddition reaction affords 1:2 and 1:3 molar cycloadducts 52 and 53, resp.

\[
\begin{align*}
\text{O}_2\text{N} & \text{Py} & \text{CH}_2=\text{CHR} & \text{Py} & \text{CH}_2=\text{CHR} \\
\text{N} & \text{R} & \text{O}^- & \text{O}^- & \text{O}^-
\end{align*}
\]

\[
R = 2\text{-pyridyl}, \quad \text{Py} = 2\text{-pyridyl}
\]

1,3-Dipolar cycloadditions of six-membered heteroaromatic betaines are a useful route for synthesis of heterocyclic compounds. Katritzky describes the cycloaddition reactions of N-substituted 3-hydroxypyridinim betaines to various dipo-
1,3-Cycloaddition reactions of 1-heteroaryl-3-hydroxypyridinium betaines with allyl alcohol resulted in tricyclic products. The starting betaines were generated in situ either from their salts or from their dimers.

Reactions with other dipolarophiles, such as 2- and 4-vinylpyridines, vinyl acetate, ethyl phenylpropiolate, are described.
In the case of butadiene, the reaction proceeds across the 2,4 positions of betaines to give expected adducts, e.g.

\[
\begin{align*}
\text{In CH}_2\text{Cl}_2-\text{CH}_2\text{Cl} \\
\text{Carius tube, } 80^\circ, \text{4d}
\end{align*}
\]

The kinetic rates, as well as the regio- and stereoselectivity of the reactions of 1-substituted 3-hydroxyopyridinium betaines have been correlated by FMO theory by Katritzky et al. Another example of 1,3-dipolar cycloaddition of heteroaromatic betaines is a simple synthesis of a new heterocyclic system, which was reported by Hanaoka et al. 8-Methoxyberberine phenol-betaine reacts with DMAD to give the cycloadduct together with the azocine.

Using unsymmetrical acetylenes, the reverse regioselectivity of reaction, contrary to the general regioselectivity of cycloadditions of heteroaromatic betaines, was found, e.g. in the reaction with methyl propiolate. Davies et al. studied the cycloadditions across the pyrimidine nucleus. 4,6-Dihydroxy-2-methylpyrimidine upon treatment with DMAD gave the adduct along with the pyridone, formed from by a retro Diels-Alder reaction.
Diels-Alder reactions

Numerous examples of Diels-Alder reactions of pyridines are known. Among the large number of cycloadditions examined by Kametani et al. the following reaction was performed:\footnote{55}

\[
\begin{align*}
\text{Me}_2\text{N} & \quad + \quad \text{Me}_2\text{C} = \text{Me} \quad + \quad \text{Me}_2\text{C} = \text{Me} \\
\text{Me}_2\text{N} & \quad + \quad \text{Me}_2\text{C} \quad \text{Br} & \quad \text{Me}_2\text{C} = \text{Me} \\
& \quad \text{Me}_2\text{C} = \text{Me} \\
\text{Me}_2\text{N} & \quad + \quad \text{Me}_2\text{C} \quad \text{Br} & \quad \text{Me}_2\text{C} = \text{Me} \\
& \quad \text{Me}_2\text{C} = \text{Me} \\
\end{align*}
\]

Kato described the Diels-Alder reaction providing a convenient route for iso-quinolines:\footnote{56}

\[
\begin{align*}
\text{Me}_2\text{N} & \quad + \quad \text{Me}_2\text{C} \quad \text{Me} \\
& \quad \text{Me}_2\text{N} \\
\end{align*}
\]

The following cycloaddition reaction was reported by Schumann and Vidic:\footnote{57}

\[
\begin{align*}
\text{Me} \quad + \quad \text{Me} \\
& \quad \text{Me} \\
\end{align*}
\]

Intramolecular cycloaddition of 2(2-allylphenoxy)pyrimidines was reported by Jojima et al.\footnote{58,59}

\[
\begin{align*}
\text{Me} \quad + \quad \text{Me} \\
& \quad \text{Me} \\
\end{align*}
\]
2. Cycloadditions of pyridinium N-methylides

Kato et al. reported the reaction of N-methylide 67 with ketene giving rise to a 1:2 molar cycloadduct 68.

\[
\begin{align*}
\text{67} & \xrightarrow{\text{CH}_2=\text{C} = \text{O}} \text{CH}_2=\text{C} = \text{O} \text{ in acetone, room temp.} \\
& \quad \rightarrow \text{COOEt} \quad \text{COOEt} \\
\end{align*}
\]

Similar reaction of N-methylide 69 gives the cycloadduct 70 as an intermediate, readily oxidized to 71. The reactions with diketene proceed in the following way:

\[
\begin{align*}
\text{67} & \xrightarrow{\text{CH}_2=\text{C} = \text{O}} \text{CH}_2=\text{C} = \text{O} \text{ in benzene, reflux} \\
& \quad \rightarrow \text{COOEt} \quad \text{COOEt} \\
\end{align*}
\]

Isoquinolinium N-methylides react with acid anhydrides to give pyrroloisoquinolines.
The 1,3-cycloaddition of pyridinium dicyano-N-methylides 72 with triphenylcyclopropene \( \text{73} \) was described by Matsumoto et al. \(^{65}\) The corresponding 1,2,3-triphenylindolizines 74 and 75 are produced; however, depending on the structures of 72, the formation of 76 may predominate:

\[
\begin{align*}
R^1, R^2, R^3 &= \text{H, Me, benzyl} \\
R &= \text{COOEt, CN} \\
R^4 &= \text{H, Me, Et, } C_6H_5
\end{align*}
\]

Similar reactions were carried out on isoquinolines \(^{65}\).

Indolizines and quinolizines are obtained in the cycloaddition reaction of cyclopropenes to 1,3-dipoles and the subsequent opening of the three-membered ring of the primary adducts. So far, little is known on the isolation of the primary adducts; Matsumoto and Uchida \(^{66}\) studied the reaction of 4-cyanopyridinium dicyano-N-methylide with triphenylcyclopropene \( \text{73} \), giving rise to 1:1 adduct \( \text{77} \) and indolizine \( \text{78} \).
3-Cyanopyridinium dicyano-N-methylide reacts with 73 under the same conditions to give the isomeric adducts 79 and 80; no indolizine was formed even upon prolonged heating:

\[
\text{CN} \quad + \quad \text{73} \quad \xrightarrow{\text{in DMP, reflux, } 5\text{h}} \quad \text{CN}
\]

\[ \text{N} \quad + \quad \text{C} \quad \text{ON} \]

Reaction of isoquinolinium bis(methoxycarbonyl)methylide with 73 afforded 1:1 adduct 81 and indolizine 82.

Ohsewe et al. 67 in the investigations of primary tricyclic adducts of this type examined the 1,3-dipolar cycloaddition of pyridazinium N-ylides with tetrahalocycloalkenes, for instance:

\[
\text{NC} \quad + \quad \text{Cl} \quad \xrightarrow{\text{in THF, room temp., } 3\text{d}} \quad \text{NC}
\]

When cyclopropenones react with pyridinium N-ylides, the primary tricyclic adducts are unstable and bicyclic products are formed. 65,68,69

The phthalazine Reissert compounds upon treatment with potassium butoxide in DMSO afford carbanion 83, which adds acrylonitrile to give 84.
3. Cycloadditions of pyridinium N-imino-ylides

In the reaction with cyclopropenones, pyridinium N-imines act often as nucleophiles, however 1,3-dipolar cycloadditions of these compounds were also observed. Kascheres et al. described the reactions of pyridinium N-imines with methylphenylcyclopropanone and dipropylcyclopropanone.

In the reaction of pyridinium N-imine iodide with 85, the 1:1 adduct 86 and its dehydrogenation product 87 are obtained.

Possible pathways of the above reactions are:

Path a involves initial 1,3-dipolar cycloaddition of pyridinium N-imine 88 to 85 resulting in 89, followed by opening of the cyclopropanone ring, with transfer of the amino hydrogen to give 90.

An alternative path b involves nucleophilic addition of 88 to 85 with hydrogen transfer, followed by intramolecular 1,5-dipolar cyclization of 91.
Although the isolated dihydrointermediate 86 is trans, initial formation of a cis-dihydrointermediate cannot be ruled out, as under the basic conditions utilized, the isomerization might be expected. For this reason the stereochemistry in 90 is not specified.

Yamashita and Masumura reported the reaction of pyridinium N-imine iodide with 2,5-dimethyl-3,4-diphenylocyclopentadienone 92, yielding the ylide 93 together with the 1:2 adduct 94:

A similar reaction carried out on quinolinium N-imine iodide gave a dehydrogenation product 96 of an unisolatable 1:1 adduct 95, along with the 1:2 adduct 97, providing from the Diels-Alder reaction of 95 with 92:
However, in the reaction with tetracyclone, the 1:1 adduct 98 could be isolated:

Ylides 93 and 96 are interesting examples of stable pyridinium and quinolinium N-imino-ylides, their stability being probably due to the construction in a five-membered ring, as well as to the presence of bulky substituents.

Ylides 93 and 96 treated with DMAD yields 1:1 adduct 99, which in the retro 1,3-dipolar cycloaddition gives 100 and 92, affording with excess of DMAD the o-terphenyl derivative 101.
The syn-anti isomerism of azomethine imines and azomethine oxides reactions with cis-3,4-disubstituted cyclobutanes was examined. In reaction of dimers of 102 and cyclobutenes 103 in boiling benzene, the exo-syn and exo-anti pyrazolines 104 and 105 were obtained:

\[
\text{N}^+ - \text{R} + \text{C}_{6}H_{5}, p-\text{NO}_{2} - \text{C}_{6}H_{4}, 2,4(\text{NO}_{2})_{2}\text{C}_{6}H_{3}
\]

\[
z = \text{Cl}, \text{CH}, \text{OAc}, 0-\text{C}-0, \text{COOMe}
\]

The exo-syn adducts 104 were characterized by tlc, their \(R_p\) being smaller than that of corresponding exo-anti adducts 105, syn-compounds possessing a larger dipole moment. No eno adducts were detected.

Gandoiffi et al. studied 1,3-dipolar cycloversions of isoxazolidines and pyrazolidines, these reactions being much less investigated than 1,3-cycloadditions. Cycloversion reactions of isoxazolidines were reported by Bianchi and Joucla, and only one example of cycloversion of pyrazolidines by Burger.

The adducts 106 to be cycloversed were obtained in the reaction of 3,4-dihydroisoquinoliniumylides with cyclopent-2-enone and cyclohept-2-enone:

\[
\text{N}^+ - \text{C}_{6}H_{5}, 0
\]

In an analogous manner, using ketals of the above \(\alpha,\beta\)-unsaturated ketones, the adducts 107 were obtained.
Cycloreversion reactions were carried out using norbornene as a 1,3-dipole scavenger. Cycloadducts 106 and 107 heated with norbornene in benzene gave adducts of the type 108.

The easier fragmentation of the adducts with α,β-unsaturated ketones as compared with that of the corresponding ketals can be explained on the basis of conjugation gain in the cycloreversion transition state of the former compounds. Kakehi et al. described the reaction of substituted pyridinium N-imines with diethyl malonate and ethyl cyanoacetate yielding pyridinium N-imino-ylides 109. These quaternize readily to give pyridinium salts, which with potassium carbonate undergo cyclization resulting in 110:

2-Picolinium N-imino-ylides (acting as 1,3-dipoles 111 or as 1,5-dipoles 111') were methylated with MeI to give the corresponding 2-picolinium salts 112 used in cycloaddition reactions.
The reaction of 112 with activated ethoxymethylene compounds, such as 113, in the presence of alkali gave the expected 2-allylidene-1,2-dihydropyridine derivative 114, which heated in xylene afforded 115, along with ethyl N-methylcarbamate.

On the other hand, 116 with the same reagents did not yield allylidene derivatives, but was converted into pyrazolopyridines 117.

---

111

\[ \text{Me} \]

\[ \text{I} \]

\[ \text{MeI} \]

\[ \text{room temp.} \]

\[ 100\% \]

112

\[ \begin{array}{c}
\text{Me} \\
\text{N} \\
\text{R}^1 \end{array} \]

\[ \text{R}^2 \]

\[ \text{N} \]

\[ \text{X} = \text{O} \]

\[ \text{COOEt} \]

113

\[ \begin{array}{c}
\text{Me} \\
\text{N} \\
\text{R}^1 \end{array} \]

\[ \text{R}^2 \]

\[ \text{X} = \text{CN} \]

\[ \text{COOEt} \]

114

\[ \begin{array}{c}
\text{Me} \\
\text{N} \\
\text{R}^1 \end{array} \]

\[ \text{R}^2 \]

\[ \text{X} = \text{CN} \]

\[ \text{COOEt} \]

115

\[ \begin{array}{c}
\text{Me} \\
\text{N} \\
\text{R}^1 \end{array} \]

\[ \text{R}^2 \]

\[ \text{X} = \text{CN} \]

\[ \text{COOEt} \]

116

\[ \begin{array}{c}
\text{Me} \\
\text{N} \\
\text{R}^1 \end{array} \]

\[ \text{R}^2 \]

\[ \text{X} = \text{CN} \]

\[ \text{COOEt} \]

117

\[ \begin{array}{c}
\text{Me} \\
\text{N} \\
\text{R}^1 \end{array} \]

\[ \text{R}^2 \]

\[ \text{X} = \text{CN} \]

\[ \text{COOEt} \]
Ohsawa et al. examined the reaction of pyridazinium N-imino-yldes with tetrahalocycloalkenes affording primary tricyclic adducts:

\[ R \begin{array}{c} N \\ \ N \end{array} + X-Y \rightarrow R \begin{array}{c} N \\ \ N \end{array}XY \]

\[ R = \text{H}, \text{C}_6\text{H}_5, \text{OEt} ; \quad Z = \text{Ac}, \text{COC}_6\text{H}_5, \text{COOEt} \]

\[ X = Y = \text{Cl} \quad X = Y = \text{Br} \quad X = \text{Br} \quad Y = \text{F} \]

Westerman and Bradsher examined regiochemistry of polar cycloadditions studying the reactions of acridizinium ion with unsymmetrical alkenes. Polar cycloadditions show a remarkable stereospecificity. For alkenes with electron-withdrawing groups, the regiochemistry of addition cannot be predicted by consideration of ground state polarization only.

The alkenes used were styrene, indene, acrylonitrile etc. In the addition with styrene, its \( \beta \) carbon atom becomes bonded to the electrophilic center of the acridizinium ion, as it can be predicted from the rules of electrophilic addition, and the product A is formed. However, the reaction with acrylonitrile affords product B, of a regiochemistry opposite to that predicted.

According to the theory of Houk, in such cases of anomalous regiochemistry, the frontier orbital theory ought to be used to rationalize the orientation. In the above reaction the \( \beta \) carbon atom with the largest HOMO coefficient of the acrylonitrile should become bonded to the 6 position of the acridizinium ion, where the LUMO coefficient is the largest.

In polar cycloadditions two stages are involved, the first being an interaction of HOMO of the donor with LUMO of the acceptor, the initial interaction
being in the nature of a charge-transfer complex formation. The great regio-
selectivity, which distinguishes cationic polar cycloadditions from other ty-
nes of cycloaddition with inverse electron demand is due to the fact that ca-
tions have a strong tendency towards the formation of charge-transfer com-
plexes.101

Other examples of cycloadditions of acridizinium ion are given by Fields102.
Vinyluracil 124 is a reactive heterocyclic diene in the Diels-Alder re-
atations, giving rise to quinazoline-5- and-6-carboxylic acids. Senda et
al.103 reported the reaction of 124 with DMAD, dimethyl maleate or dimethyl
fumarate, resulting in quinazolinedione 125. Similar reaction of 124 with
N-phenylmaleimide gave the 1:1 adduct 126.

\[
\text{DMAD} \quad \xrightarrow{\text{in MeCN, room temp., 19\%}} \quad \begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\begin{array}{c}
\text{O} \\
\text{NMe}_2
\end{array} \\
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\begin{array}{c}
\text{O} \\
\text{NMe}_2
\end{array} \\
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\begin{array}{c}
\text{O} \\
\text{NMe}_2
\end{array} \\
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\begin{array}{c}
\text{O} \\
\text{NMe}_2
\end{array} \\
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\begin{array}{c}
\text{O} \\
\text{NMe}_2
\end{array} \\
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\begin{array}{c}
\text{O} \\
\text{NMe}_2
\end{array} \\
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\begin{array}{c}
\text{O} \\
\text{NMe}_2
\end{array} \\
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\begin{array}{c}
\text{O} \\
\text{NMe}_2
\end{array} \\
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\begin{array}{c}
\text{O} \\
\text{NMe}_2
\end{array} \\
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\begin{array}{c}
\text{O} \\
\text{NMe}_2
\end{array} \\
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\begin{array}{c}
\text{O} \\
\text{NMe}_2
\end{array} \\
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\end{array}
\]

124 \quad \xrightarrow{\text{in benzene, reflux, 71\%}} \quad 125

\[
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\begin{array}{c}
\text{O} \\
\text{NMe}_2
\end{array} \\
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\begin{array}{c}
\text{O} \\
\text{NMe}_2
\end{array} \\
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\begin{array}{c}
\text{O} \\
\text{NMe}_2
\end{array} \\
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\begin{array}{c}
\text{O} \\
\text{NMe}_2
\end{array} \\
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\begin{array}{c}
\text{O} \\
\text{NMe}_2
\end{array} \\
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\begin{array}{c}
\text{O} \\
\text{NMe}_2
\end{array} \\
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\end{array}
\]

In the photocycloaddition of uracil with olefins, the substitution of 5H for
P remarkably enhances the regioselectivity104. Greenlee et al.105,106-108
reported the following reaction:

\[
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\begin{array}{c}
\text{O} \\
\text{NMe}_2
\end{array} \\
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\begin{array}{c}
\text{O} \\
\text{NMe}_2
\end{array} \\
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\begin{array}{c}
\text{O} \\
\text{NMe}_2
\end{array} \\
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\begin{array}{c}
\text{O} \\
\text{NMe}_2
\end{array} \\
\begin{array}{c}
\text{Me} \\
\text{Me}
\end{array} \\
\end{array}
\]

100\%
The 1,3-dipolar cycloaddition reactions of fervenulin-4-oxide, as well as of its 3-alkyl derivatives were investigated by Senga et al.\textsuperscript{109}. The reaction of 127 with DMAD in toluene at 95° afforded pyrrolo[3,2d]pyrimidine 128, while in refluxing toluene the unexpected pyrrolo[3,2d]pyrimidine 129 was formed.

![Diagram](image)

Similar reactions were carried out with methyl propiolate and ethyl phenylpropiolate\textsuperscript{109}.

Photocyclization being a useful method in organic synthesis, some examples of this reaction should be included here. Thus, Veeramani et al.\textsuperscript{110} reported reactions of 3-vinyl-4-phenylquinolines, for instance:

\[
\text{R = Me, Cl}
\]

Lenz showed, that in the irradiation of the compound 130, containing a perdeuteriobenzoyl group an o-deuteron was transferred in a [1,5]-shift with the formation of 131:  

![Diagram](image)
Numerous examples of this type of photocyclization involving [1,5]-group migrations were described by Hinomiya et al.\textsuperscript{112} 

Kametani et al. studied conversion of \textsuperscript{122} via the oxyprotoberberine \textsuperscript{133} to naturally occurring dl-xylopinine \textsuperscript{134}, as well as investigated reactions of dl-o-substituted bromo- and methoxypiperidines\textsuperscript{114}.

![](image)

The following conversion, described by Ogata et al.\textsuperscript{115}, where pyridine ring can be replaced by other heterocyclic systems can serve as useful synthetic route to a variety of heterocycles.

![](image)
REFERENCES
7. V. Šimánek and V. Freininger, Heterocycles, 1977, 6, 475.
15. R.M. Acheson and R. Flowerday, J.C.S.Perkin I, 1975, 394; R.M. Acheson,
   12, 231.
   44, 285.
20. M. Yoshida, Y. Ishiguro, T. Yamamori, M. Aoyama, T. Endo, H. Noda, R. Funakoshi,
    S. Seei and M. Hamana, 11th Congress of Heterocyclic Chemistry, Kanasawa,Japan 1978,
    Heterocycles, 1979, 12, 167; M. Hamana, private information.
    1976, 98, 5671.
35. R.M. Acheson and G. Paglietti, Heterocycles, 1979, 12, 695.
42. E. Matsumura, M. Ariga and Y. Tohda, Heterocycles, 1979, 12, 160.
80. R. Gandolfi, M. Ratti, L. Toma and C. De Michelli, Heterocycles, 1979, 12, 897.
82. R. Gandolfi, L. Toma and C. DeMichelli, Heterocycles, 1979, 12, 5.

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