CROATICA CHEMICA ACTA CCACAA 59 (1) 89—108 (1986)

YU ISSN 0011-1643
CCA-1629 UDC 547.831.1
Author's Review

The Reaction of Dihydro-intermediates Derived from Pyridine and Quinoline *N*-oxides

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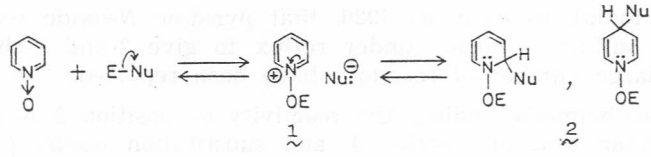
Received June 4, 1985

Some representative results obtained in the author's laboratory at Kyushu University from the studies on reactions of dihydro intermediates derived from quinoline and pyridine *N*-oxides, mainly acylating agents, have been reviewed.

Aromatic *N*-oxides[1–4] undergo a variety of nucleophilic reactions with a number of reagents (E-Nu). These reactions involve the initial formation of an adduct *1* by the attack of $E^{\oplus}$ on the *N*-oxide oxygen atom, and the subsequent addition of $Nu:^{\ominus}$ to the α- or/and γ-position to give a 1,2- or/and 1,4-dihydro intermediate *2*, as illustrated by pyridine *N*-oxide in Eq 1.



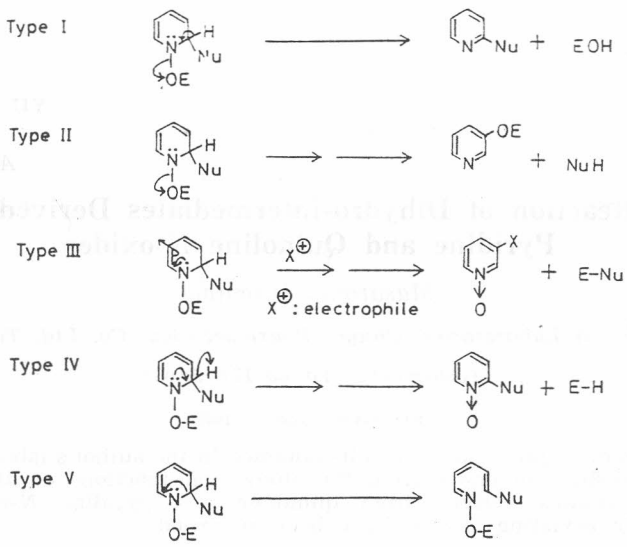
(Eq 1)

Although some reactions of *1* other than the formation of *2* are known, they are beyond the scope of this article. The great number of nucleophilic reactions of aromatic *N*-oxides are due to the varied reactivities of *2*, *i. e.* either a dienehydroxylamine or an enehydroxylamine system.

For a better understanding of these reactions, they have been classified into five types as shown by 1,2-dihydropyridine in Chart 1; Type I, formation of α- or/and γ-substitution product accompanied by deoxygenation of the *N*-oxide function; Type II, formation of deoxygenated β-substitution product; Type III, electrophilic substitution by means of the enamine-like moiety of *2*; Type IV, nucleophilic displacement of the α-hydrogen; Type V, ring cleavage reaction by electrocyclic reaction.

This article describes some representative results obtained from the studies on reactions of dihydro intermediates derived from quinoline and pyridine *N*-oxides, mainly with acylating agents, undertaken in our labo-

Chart 1



ratory of the Kyushu University. However, Type V reactions will not be included.

(1) Type I Reactions: The Formation of Deoxygenated α or/and γ-Substitution Product

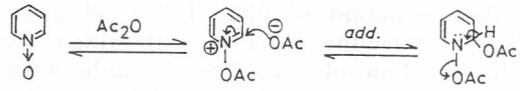
The type I reaction proceeds by the addition-elimination mechanism, and since Meisenheimer found, as early as 1926, that pyridine *N*-oxide reacted with phosphoryl or sulfuryl chloride under reflux to give 2-and 4-chloropyridines[5,6] a very large number of reactions have been reported.[1-4]

In spite of Meisenheimer's finding, the reactivity of position 2 is generally much higher than that of position 4, and substitution occurs predominantly, or exclusively, at position 2 in most of the reported reactions, except for a few cases. For instance, the reaction of pyridine *N*-oxide with hot acetic anhydride (Ac_2O) gave only 2-pyridone *3*[7] (Eq 2).

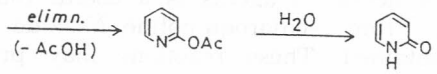
When the reaction is conducted in the presence of other nucleophiles, the added nucleophilic species can be introduced in place of $Nu:^{\ominus}$ of the reagent in many cases; the formation of carbostyril *5* and 2-cyanoquinoline *6* from quinoline *N*-oxide is well known[8] (Eq 3). We were able to isolate 1,2-dihydroquinoline *4* in ca. 50% yield.[9]

In order to introduce a variety of substituents into quinoline and pyridine rings, we carried out an extensive study of the reactions of quinoline and pyridine *N*-oxides with various nucleophiles in the presence of acylating agents. Eq 4 is a simple preparation of 2-alkoxyquinolines *7*.[10]

When quinoline *N*-oxide was treated with *prim.* or *sec.* amines in the presence of tosyl chloride (TsCl), 2-amino-quinolines were formed, sometimes with a small amount of the 4-amino-isomers; the reaction with aniline



(Eq 2)



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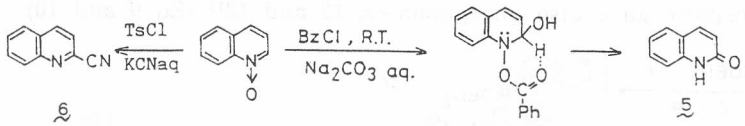
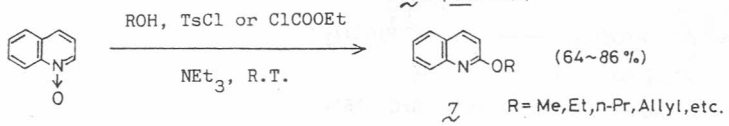


6 4 (ca. 50%) 5

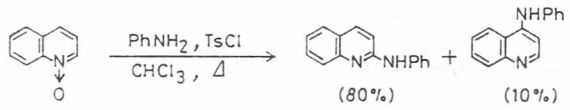
(Eq 3)



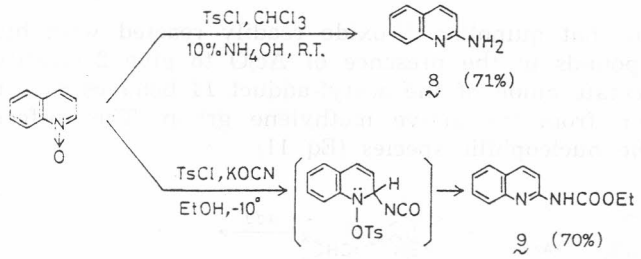
7 R= Me,Et,n-Pr,Allyl,etc.

(Eq 4)

is shown in Eq 5.[11] 2-Aminoquinoline *8*[11] and its ethyl carbamate *9*[12] were also prepared in good yields (Eq 6); ethanol is essential for the smooth formation of *9*. No satisfactory results were obtained by the use of benzoyl chloride (BzCl) or Ac_2O.

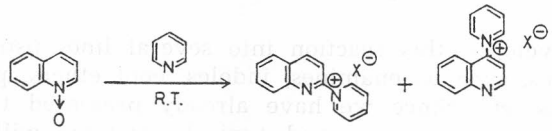


(Eq 5)



(Eq 6)

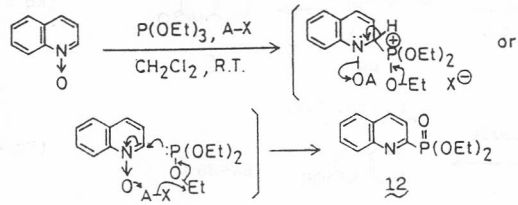
Furthermove, pyridine was found to react also as a nucleophile to give quinolyl-pyridinium salts *10* and *11*.[13] The high regioselectivity was obtained by the choice of the acylating agent (Eq 7). The reaction of pyridine *N*-oxide in the presence of TsCl gave 2-substituted pyridine and a smaller amount of the 4-isomer, but BzCl was not effective in this case.



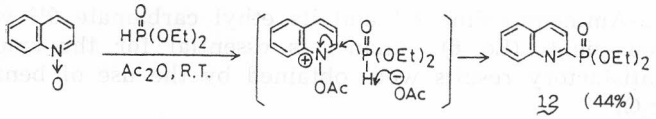
	10	11
BzCl	93.0 %	5.3 %
TsCl	5.3 %	94.3 %

(Eq 7)

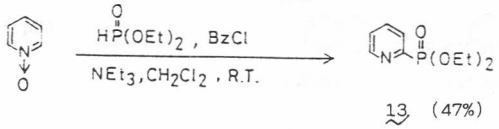
Redmore[14] reported on the formation of diethyl 2-pyridinephosphonate by treatment of methosulfate of pyridine *N*-oxide with alkali diethylphosphonate. We found that the reaction of quinoline *N*-oxide with triethyl phosphite in the presence of acylating agents is a useful route to 2-quinolinephosphonate *12*[15] (Eq 8). From 2-chloroquinoline *N*-oxide the corresponding 4-phosphonate was obtained. These reactions may proceed through phosphonium salts or the Michaelis-Arbuzov type reaction. The reactions with diethyl phosphite gave also phosphonates, *12* and *13*[15] (Eq 9 and 10).



(Eq 8)

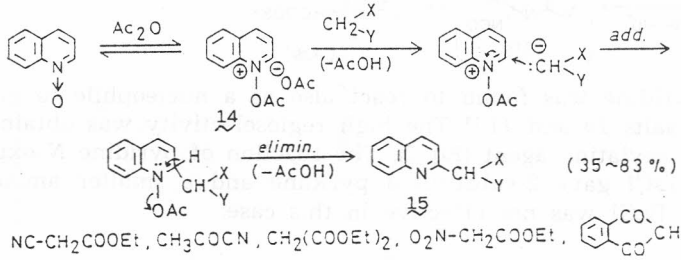


(Eq 9)



(Eq 10)

In 1963, we found that quinoline *N*-oxide readily reacted with highly active methylene compounds in the presence of Ac_2O to give 2-substituted quinolines *15*.[16] The acetate anion of the acetyl-adduct *14* behaves as a base and abstracts a proton from the active methylene group. The so-formed carbanion reacts as the nucleophilic species (Eq 11).

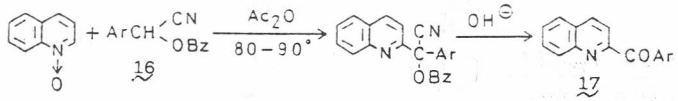


(Eq 11)

Since then, we have developed this reaction into several lines using a variety of carbon nucleophiles, such as enamines, indoles, enol ethers, pyridinium salts, Wittig reagents, *etc.* Since we have already presented three surveys on this subject,[17–19] only the basic and typical reactions will be described.

Some recent developments of the reactions with active methylenes in the presence of Ac_2O are as follows. Nucleophilic aroylation was successfully

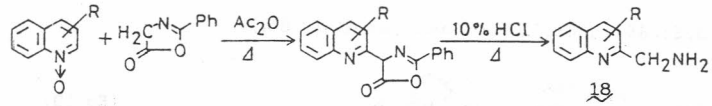
achieved by the use of *O*-benzoyl cyanohydrins of aromatic aldehydes *16*[20]; the nucleophilic species is the carbanion derived from *16*, and alkaline hydrolysis of products gives aroylation products *17* (Eq 12). Pyridine *N*-oxide reacted similarly, though in lower yields.



(Eq 12)

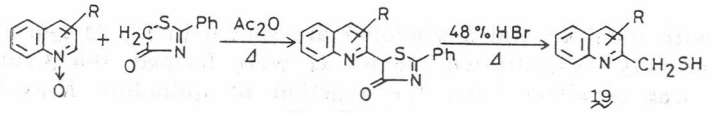
Ar = p-O_2N-C_6H_4 : 76 %, p-NC-C_6H_4 : 66 %, 2-Py : 54 % etc.

When oxazoline,[21] thiazolone[22] or rhodanine[23] were used as nucleophiles, α-aminomethyl or α-mercaptomethyl derivatives, *18* or *19*, were obtained in good yields after acid hydrolysis. The reaction proceeded also with pyridine and isoquinoline *N*-oxides (Eq 13 and 14).



(Eq 13)

(49 – 93 %) (ca. 70 %)

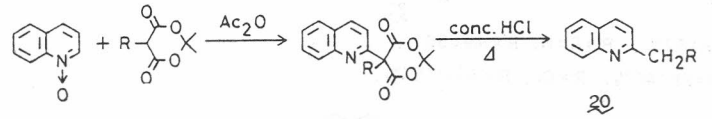


(Eq 14)

(68 – 93 %) (51 – 87 %)

R = H, 4-Me, 4-OMe, 4-Cl, 4-N⬡O, 3-Br

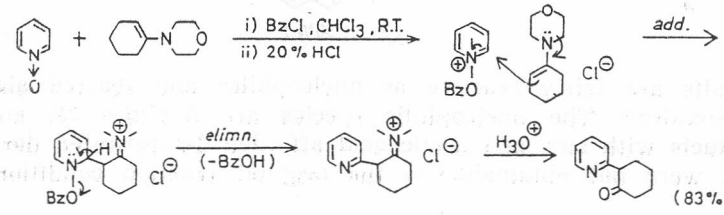
A general synthetic method for the preparation of 2-alkylquinolines *20* was established by treatment of quinoline *N*-oxide with Meldrum's acid and Ac_2O, followed by acid hydrolysis[24] (Eq 15).



(Eq 15)

R = H, Me, Et, n-C_6H_{13} (48 – 81 % ; 83 – 94 %)

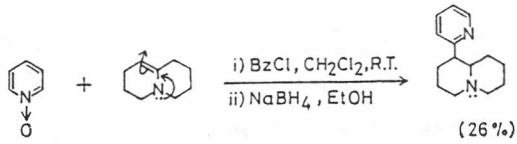
The reaction of aromatic *N*-oxide with enamines in the presence of BzCl follows the course exemplified in Eq 16.[25] The reactivity of this reaction is very high, and 4-substitution also occurs with some 2-substituted *N*-oxides, such as 2-chloroquinoline and quinaldine *N*-oxides.[26]



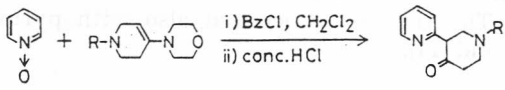
(Eq 16)

(83 %)

Besides cyclohexanone enamines, enamines of isobutylaldehyde[27] and *N*-acyl-4-piperidones,[28] and dehydroquinolizidines,[29] dimethylaniline,[11] and antipyridine[30] reacted similarly. Some examples are shown in Eq 17, 18 and 19.

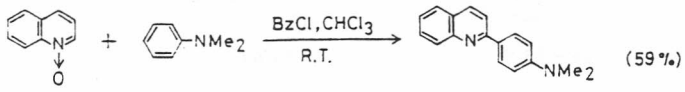


(Eq 17)



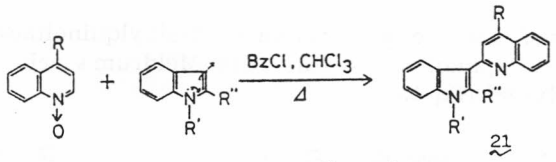
(Eq 18)

R=COOEt: 85 %, CH_3CO: 51 % etc. (R=alkyl : 0 %)



(Eq 19)

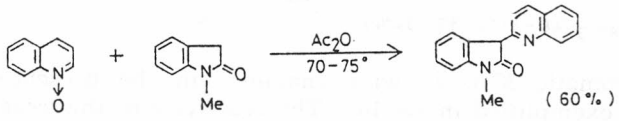
The reactions with indoles[31] and oxyindole[32] are shown in Eq 20 and 21. While in the former only α-substituted indoles *21* were formed, the β-substituted indole *22* was obtained from the reaction of quinoline *N*-oxide with 3-methoxyindole, though in a low yield[33] (Eq 22).



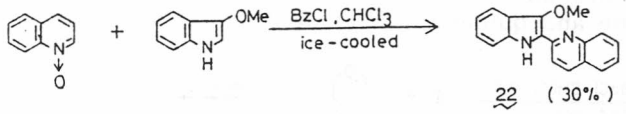
(Eq 20)

21

R = R' = R'' = H : 67 %, R = R'' = H, R' = Me : 56 %,
R = R' = H, R'' = Ph : 40 %, R = Cl, R' = R'' = H : 54 %.

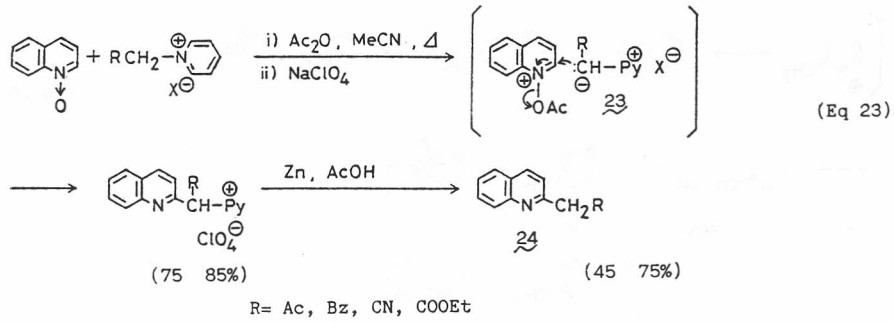


(Eq 21)



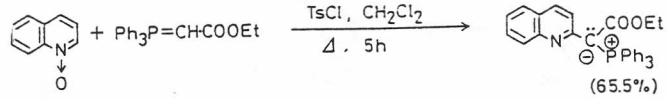
(Eq 22)

Pyridinium salts are fairly reactive as nucleophiles and reacted also with pyridine *N*-oxides.[35] The nucleophilic species are *N*-ylides *23*, and treatment of products with zinc and acetic acid afforded 2-substituted derivatives *24* which were not obtainable in the original reaction conditions (Eq 23).



(Eq 23)

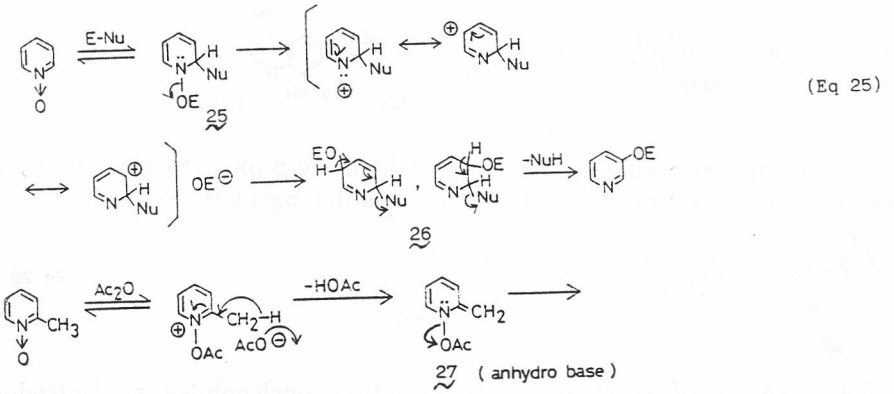
While nitrones undergo 1,3-dipolar cycloaddition with Wittig reagents to give cycloadducts,[35] aromatic *N*-oxides resist this cycloaddition.[37] However, some resonance-stabilized Wittig reagents reacted, as *P*-ylides, with quinoline *N*-oxide in the presence of TsCl to give quinolyl-substituted ylides[15] (Eq 24).



(Eq 24)

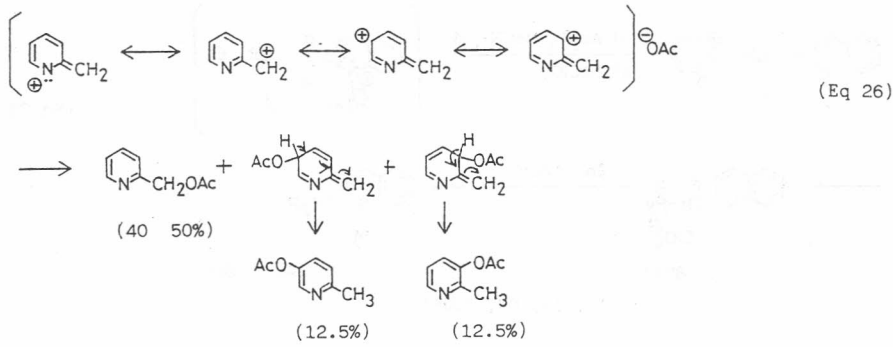
(2) Type II Reaction: The Formation of Deoxygenated β-Substitution Product

The key step of this type of reactions is the cleavage $>\dot{N}-\overset{\curvearrowright}{O}E$ in a dihydro intermediate *25*. This causes electrondeficiency at the β-position, which is in turn attacked by $OE^{\ominus}$ to give a second dihydro intermediate *26*, followed by elimination of NuH to give the product. We shall illustrate it using a 1,2-dihydropyridine *25* in Eq 25.



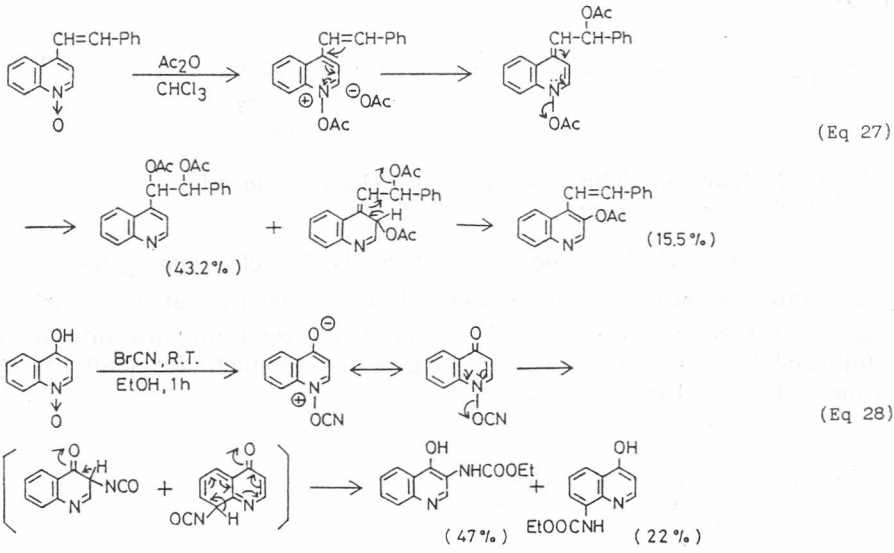
(Eq 25)

When the α- or γ-substituent hears an active hydrogen, the anhydro base *27* derived from an acyl-adduct acts as 1,2-dihydro intermediate, and nucleophilic attack may occur also at the side chain.[38] The reaction of 2-picoline *N*-oxide with Ac_2O is a typical example[39] (Eq 26).



(Eq 26)

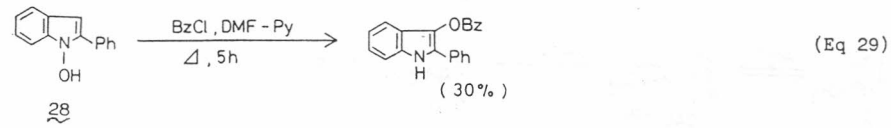
Eq 27[40] and 28[41] are two examples of our findings on these reactions (Eq 27 and 28).



(Eq 27)

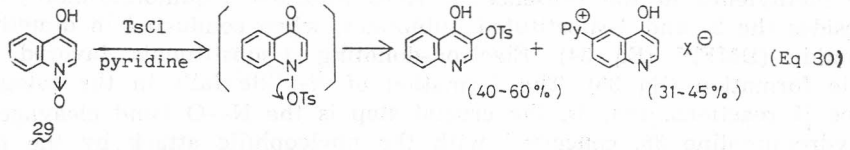
(Eq 28)

The enehydroxylamine system of 1-hydroxy-2-phenylindole *28* undergoes the same type of reactions with acylating agents[42] (Eq 29).

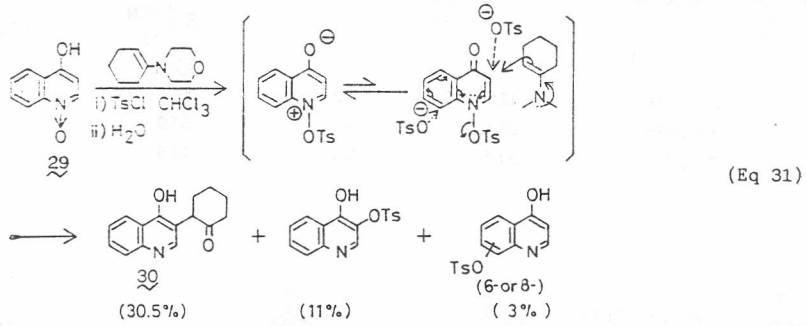


(Eq 29)

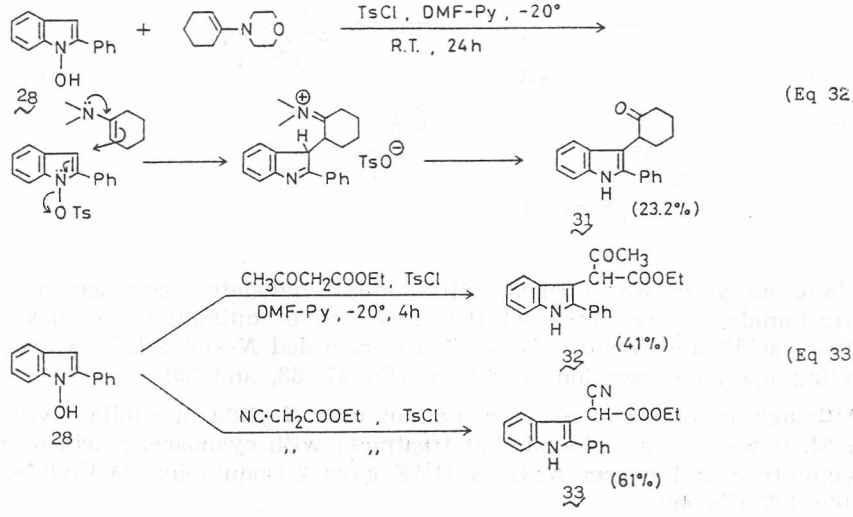
The number of reactions in which other nucleophiles are introduced instead of $OE^{\ominus}$ is small when compared with the type I reactions,[43,44] but the introduction of a pyridinium residue was observed in reactions of 2- and 4-hydroxyquinoline *N*-oxides with pyridine and TsCl.[45] Eq 30 represents the reaction of 4-quinolinol *N*-oxide 29 with pyridine.



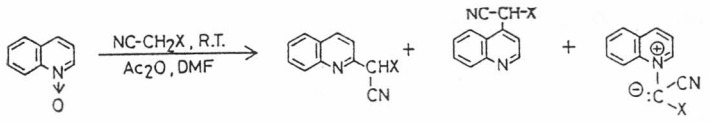
Furthermore, the introduction of a carbon-substituent could be realized by the reaction of *29* with 1-morpholinocyclohexene in the presence of TsCl, the 3-substituted quinoline *30* being formed[26b] (Eq 31). However, the scope is considerably limited in spite of the efforts.



On the other hand, reactions of the 1-hydroxyindole *28* with some carbon nucleophiles in the presence of TsCl proceeded rather smoothly to give β-substituted indoles, *31*, *32* and *33*[42] (Eq 32 and 33). Since 1-hydroxyindoles are now easily accessible,[46] this type of reactions is apparently a promising route to β-substituted indoles.

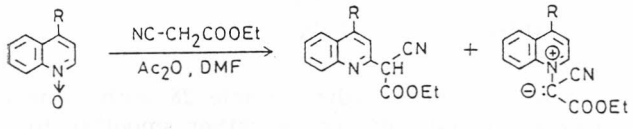


In 1978, we found that the reaction of quinoline *N*-oxide with some active methylenes in the presence of Ac_2O afforded 1-quinolino-methylides *34*, besides the 2- and 4-substituted quinolines, when conducted in dimethylformamide (DMF)[47] (Eq 34). Electron-donating 4-substituents favored the *N*-ylide formation (Eq 35). The formation of *N*-ylide falls in the category of type II reactions; that is, the crucial step is the N—O bond cleavage in a dihydroquinoline *35*, concerted with the nucleophilic attack by the preformed side chain anion at the nitrogen cation to give an aziridine intermediate *36* (Eq 36).



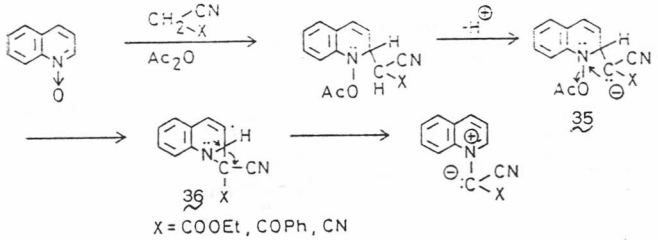
(Eq 34)

X = COOEt	32.0 (%)	4.2 (%)	54.0 (%)
X = COPh	29.4	–	61.0
X = CN	23.0	5.3	11.6



(Eq 35)

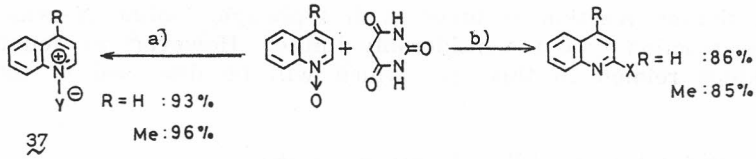
R = Me	39.0 (%)	24.5 (%)
R = OMe	4.6	39.0
R = NH_2 (NHAc)	1.0	90.0



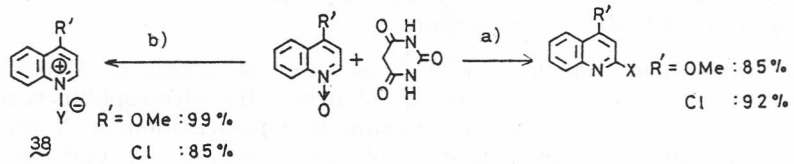
(Eq 36)

While no ylide was formed with diethyl malonate, acetylacetone, and cyanoacetamide, it was disclosed that reactions of quinoline *N*-oxides with barbituric acid[48] and Meldrum's acid[24] also afforded *N*-ylides (*37*, *38*, and *39*) depending upon the reaction conditions (Eq 37, 38, and 39).

Although isoquinoline *N*-oxide did not give *N*-ylide in similar reactions to Eq 34, it was recently found that treatment with cyanoacetic acid or benzoylacetonitrile and excess Ac_2O in DMF gave 2-isoquinolino-methylide, for example *40*[49] (Eq 40).

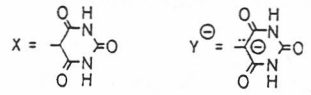


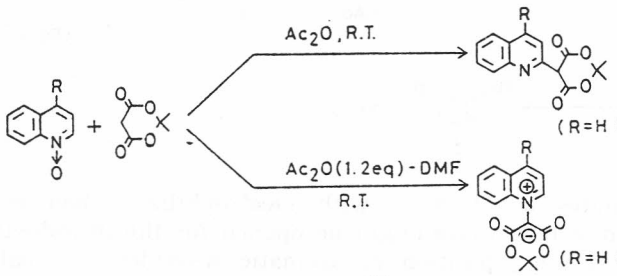
37 (Eq 37)



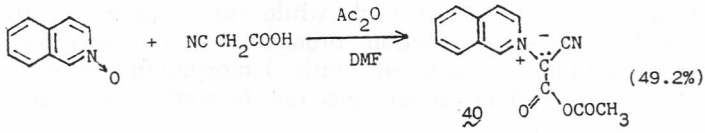
38 (Eq 38)

a) Ac_2O(1.2 eq)–DMF, R.T.
b) Ac_2O(1.2 eq)–DMF, 90°



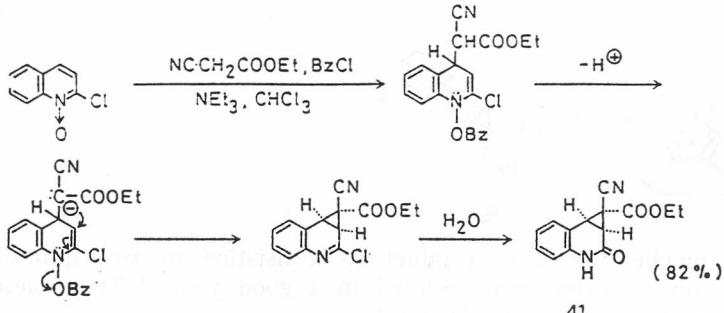


39 (Eq 39)



40 (Eq 40)

Furthermore, it was discovered that treatment of 2-chloroquinoline *N*-oxide with ethyl cyanoacetate and BzCl in the presence of triethylamine produced a cyclopropa[c]quinoline *41* in a high yield[50] (Eq 41). This novel reaction is also a type II reaction.

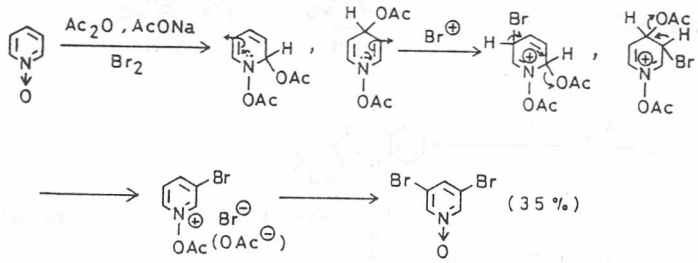


41 (Eq 41)

Although a similar reaction occurred with 2-phenylquinoline *N*-oxide, the scope of this reaction type is considerably limited. However, we found interesting reactions related to this one, which will be described in the next section.

(3) Type III Reaction: Electrophilic Reactions at the β-Position of a Dihydro Intermediate

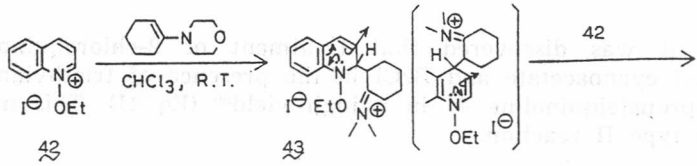
In 1957, Ochiai and Kaneko found β-nitration of aromatic *N*-oxides with acyl nitrates, and showed that the key step was the electrophilic reaction at the β-position by means of the enamine-like polarization of *N*-acyloxydihydrointermediate.[51] As an extension of this reaction, we performed β-bromination by treatment with bromine and Ac_2O[52] (Eq 42).



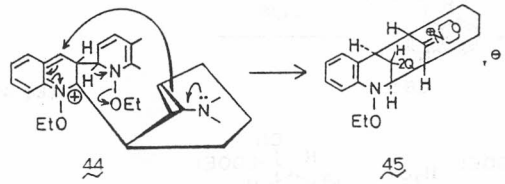
(Eq 42)

If dihydro intermediates could react with electrophilic carbon compounds by this mechanism, a new route might be opened for the introduction of carbon-substituents into the β-position of aromatic *N*-oxides. To realize this possibility, various reactions were examined, but no satisfactory results have been obtained so far.[53]

However, in 1975, we happened to find, while investigating reactions with enamines, that this type of reaction process was involved in the reaction of *N*-ethoxyquinolinium iodide *42* with 1-morpholinocyclohexene. The anticipated 2-(2-quinolyl)cyclohexanone was not formed at all, but, in-



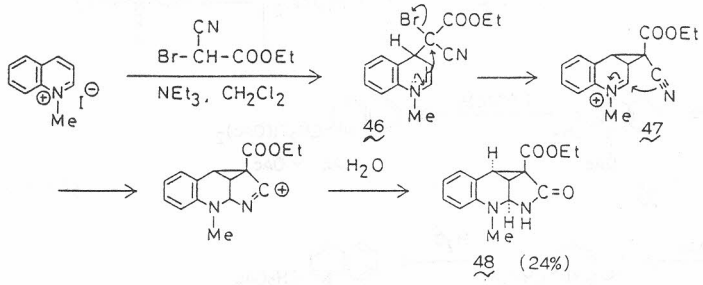
(Eq 43)



stead, a novel tricyclic nonplanar product *45*, consisting of two quinoline rings and an enamine residue, was isolated in a good yield.[54] The reaction path and structure of *45* are shown in Eq 43.

The 3-position of the first 1,2-dihydroquinoline *43* attacks as the 2--position of another molecule of *42* to give the second intermediate *44* containing both 2,3-dihydroquinolinium and 1,2-dihydroquinoline structures. One molecule of ethanol is eliminated from the 1,2-dihydroquinoline moiety of *44* and the enamine residue attacks at the electron-deficient 4-position of the dihydroquinolinium moiety to give *45*. While *N*-alkoxyquinolinium salts underwent the same reaction type also with enamines of diethyl ketone and cyclopentanone, no satisfactory results were obtained with pyridine, quinaldine and lepidine *N*-oxides.

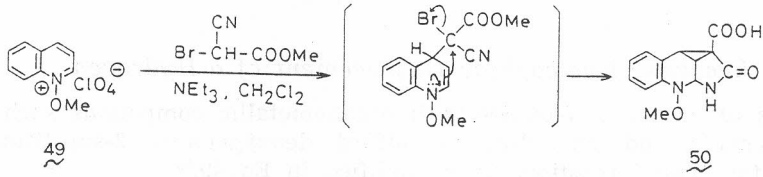
The mechanistic considerations of the reaction of Eq 41 suggest that the reaction of *N*-alkylquinolinium salt with active methylenes having a good leaving group could also give a cyclopropa[c]quinoline by the enamine--like reactivity of the initially formed 1,4-dihydroquinoline *46*. When quinoline methiodide was treated with ethyl bromocyanoacetate in the presence of triethylamine, a cyclopropane ring formed in fact, but the reaction proceeded further to give product *48* by the nucleophilic attack of the cyano group at the immonium moiety of the cyclopropa[c]quinoline *47*[55] (Eq 44).



(Eq 44)

Bromocyanoacetamide, α-bromophenylacetonitrile, *O*-tosylate of cyanohydrin of aromatic aldehydes underwent the same type of reactions with *N*-alkylquinolinium salts. In these reactions, the formation of a five-membered lactam enables the isolation of stable products. While the formation of a cyclopropane ring could be affirmed, for instance, in the reaction of quinoline methiodide with diethy bromomalonate, the isolation of the cyclopropa[c]quinoline was not successful.[56]

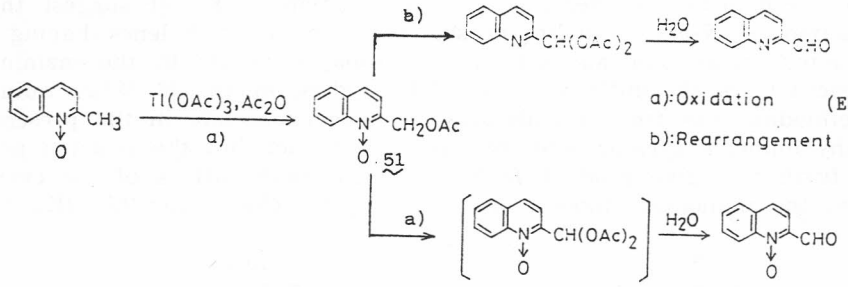
Interestingly, it was found that the reaction of *N*-methoxyquinolinium perchlorate *49* with methyl bromocianoacetate in the presence of triethylamine also afforded product *50* of the same type[56] (Eq 45).

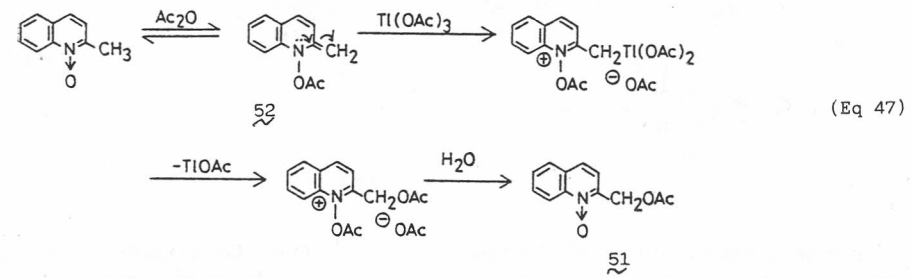


(Eq 45)

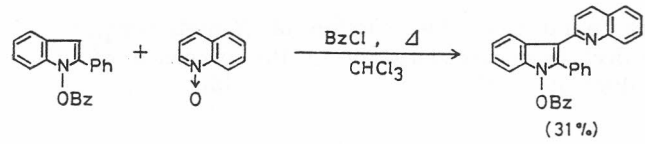
While *N*-alkoxy-dihydro compounds are apparently more reactive than their *N*-acyloxy analogues toward this type of reaction, the latter can also undergo electrophilic reactions, as demonstrated by β-nitration and β-bro-

mination of aromatic *N*-oxides in the presence of acylating agents. We discovered that the reaction of quinaldine *N*-oxide with thallium triacetate in the presence of Ac_2O afforded 2-acetoxymethylquinoline *N*-oxide *51*, which further underwent the same type of oxidation or rearrangement by means of Ac_2O, depending upon the reaction conditions[57] (Eq 46). The formation of *51* is rationalized by oxidation of anhydro base *52* with thallium triacetate; this is the first example in which the enamine-like reactivity of anhydro base was noticed (Eq 47). Similar results were also obtained with lepidine, 2- and 4-picoline *N*-oxides.





The formation of 1-benzoyloxy-2-phenyl-3-(2-quinolyl)-indole from the reaction of 1-benzoyloxy-2-phenylindole with quinoline *N*-oxide in the presence of BzCl is further evidence for the potentiality of enehydroxylamine systems for electrophilic reactions[58] (Eq 48).



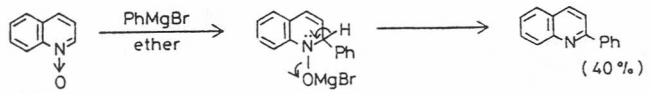
(Eq 48)

(4) Type IV Reaction: Nucleophilic Displacement of α-Hydrogen

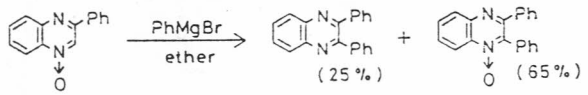
Reactions of aromatic *N*-oxides with organometallic compounds such as Grignard reagents and phenyllithium afford deoxygenated 2-supstitution products by the type I reaction, as exemplified in Eq 49.[59]

In 1962, Hayashi and his co-workers found that some benzodiazine *N*-oxides reacted with Grignard reagents to give the corresponding 2-substituted *N*-oxides, as the major products in some cases along with the deoxy-

genated products, as exemplified in Eq 50.[60] Since then similar formation of α-substituted *N*-oxides has been reported with various *N*-oxides.[61,62]

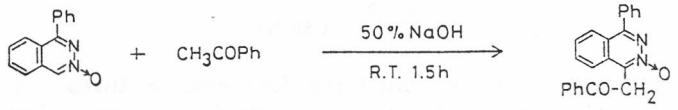


(Eq 49)



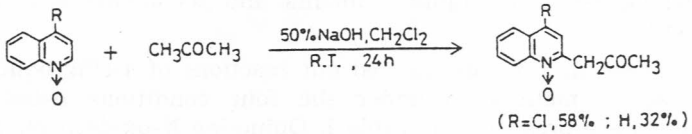
(Eq 50)

In 1967, Hayashi and Ohishi[63] reported that 4-phenacyl-1-phenylphthalazine 3-oxide *53* was formed, though in a poor yield, from the reaction of 1-phenylphthalazine 3-oxide with acetophenone in the presence of 50% NaOH (Eq 51). In the course of studies of the phase-transfer-catalyzed reactions of 4-chloroquinoline *N*-oxide with some carbanions[64] we also found that reactions with some active methylenes in the presence of NaOH brought about the introduction of carbon-substituents into the 2-position, the 4--chloro group not being attacked[65] (Eq 52 and 53).

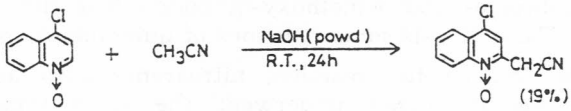


53 (13%)

(Eq 51)



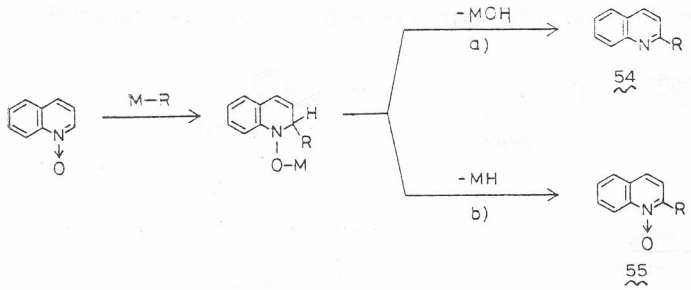
(Eq 52)



(Eq 53)

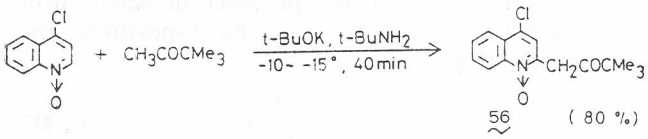
These findings suggest that 1,2-dihydro intermediates formed from aromatic *N*-oxides and organometallics can undergo further transformation following two courses, a) and b); course a) is the formation of deoxygenated 2-substituted product *54* by elimination of metal hydroxide (type I), and course b) is the formation of 2-substituted *N*-oxide *55* by elimination of metal hydride (type IV reaction) (Eq 54).

Although course b) is apparently accelerated by the presence of an oxidant, it also seems possible that the choice of course is principally dependent upon the nature of M—O bond rather than the presence or absence of an oxidant.[66]



(Eq 54)

While examining the possibility of $ArS_{RN}1$ reaction[67] of 4-chloroquinoline *N*-oxide, we happened to find that the potassium *tert*-butoxide (*t*-BuOK)-catalyzed reaction with pinacolone in *tert*-butylamine (*t*-$BuNH_2$) gave 4-chloro-2-pinacolylquinoline *N*-oxide *56* in a high yield, without any participation of the 4-chloro group[68] (Eq 55).



(Eq 55)

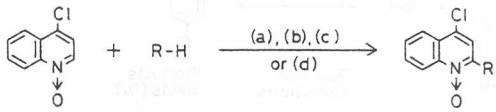
Some preliminary examinations revealed the following features: (1) the reaction is not substantially altered by tetraphenylhydrazine or *p*-dinitrobenzene; (2) the reaction proceeds smoothly with active methylenes of rather low acidity, but not with highly active ones, such as ethyl cyanoacetate; (3) among the so far examined bases, *t*-BuOK, *n*-BuLi, KNH_2 and $NaNH_2$ are highly effective; (4) *t*-$BuNH_2$, liquid ammonia and tetrahydrofuran are fairly efficient solvents.

On the basis of these findings, we carried out reactions of 4-chloroquinoline *N*-oxide with active methylenes under the four conditions listed in Table I. Some reactions are presented in Table I. Quinoline *N*-oxide itself and some derivatives, such as 3-bromo- and 4-methoxy-quinoline *N*-oxides, also reacted in a similar manner; Table II lists some reactions of quinoline *N*-oxide.

While pyridine *N*-oxide resisted the reaction, nitroarenes such as *p*-chloronitrobenzene and nitronaphthalenes underwent the same type of reaction, though their reactivities were somewhat lower. Table III shows the reaction of *p*-chloronitrobenzene.

Although the details of the mechanism have not been established, the overall reaction in the quinoline *N*-oxide series is the nucleophilic displacement of α-hydrogen. It was found that the presence of oxygen accelerated the reaction in both the quinoline *N*-oxide and nitroarene series, but the effect was much smaller in the reactions of quinoline *N*-oxides than in those nitroarenes. The combination of the base and solvent seems to be a very important factor for the reaction to proceed. We have already found many interesting reactions in an extension of the above-mentioned work, which will be the subject of another article.

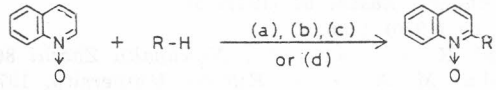
Table I. Reactions of 4-Chloroquinoline N-Oxide



-R	Reaction Conditions	Products Yields (%)
$-CH_2COCMe_3$	(b), 30min	54.0
	(c), 2h	89.8
	(d), KNH_2, 2h	69.5
$-CH(Me)COCH_3$	(c), 1h	64.7
$-CH_2COPh$	(a), 20min	65.0
	(c), 2h	41.6
	(d), KNH_2, 2h	33.2
$-CH_2COOCMe_3$	(a), 1h	62.0
	(b), 1h	67.0
$-CH_2COOEt$	(a), 1h	18.5

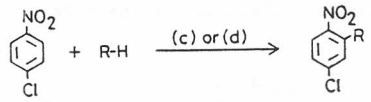
(a) t-BuOK, $t\text{-BuNH}_2$, $-10 \sim -15°$, (b) n-BuLi, $t\text{-BuNH}_2$, $-10 \sim -15°$, (c) t-BuOK, liq NH_3, $-70°$, (d) KNH_2 or $NaNH_2$, liq NH_3, $-70°$.

Table II. Reactions of Quinoline N-Oxide



-R	Reaction Conditions	Products Yields (%)
$-CH_2COCMe_3$	(a), 2h	81.0
	(b), 2h	65.0
	(c), 2h	47.3
	(c), 2h	46.7
	(d), KNH_2, 2h	16.2
$-CH_2COOCMe_3$	(a), 2h	34.0
	(b), 2h	47.7
	(c), 2h	40.4
$-CH_2CN$	(a), 1h	44.4
	(c), 2h	25.9

Table III. Reactions of 4-Chloronitrobenzene



-R	Reaction Conditions	Products Yields (%)
$-CH_2COCH_3$	(c), 8 h	56.5
$-CH_2COCMe_3$	(c), 25h	62.4
	(d), KNH_2, 4h	43.9
$-CH_2COOCMe_3$	(c), 3h	21.0
$-CH_2CN$	(c), 6h	22.0

Acknowledgment. — The author wishes to thank his many associates and students who collaborated in these researches in the Laboratory of Organic Chemistry, Faculty of Pharmaceutical Sciences, Kyushu University.

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POVZETEK

Reakcije dihidro intermediatov iz piridin in kinolin *N*-oksidov

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Dihidro derivati piridin *N*-oksida in kinolin *N*-oksida, ki nastanejo po adiciji nukleofila, se lahko pretvorijo dalje na več načinov. V preglednem članku so tovrstne reakcije razdeljene v pet skupin. V prvo skupino so uvrščene reakcije, pri katerih pride do substitucije na položaju 2 ali 4 in deoksigeniranja, v drugo substitucije na položaju 3 z istočasnim deoksigeniranjem, v tretjo pa elektrofilne substitucije na položaju 3. Četrta skupina obsega reakcije, kjer pride do nukleofilne zamenjave vodika na položaju 2, a v peti skupini so reakcije pri katerih pride do odprtja obroča.