**Ethyl 1-Benzyl-2-oxo-3-methyl-1,2,3,4-tetrahydro-5-pyrimidinecarboxylate (XXIII)**——To a solution of 68 mg. of V in 1.0 ml. of abs. dioxane, 12 mg. of NaH (50% oil) and 0.2 ml. of $CH_3I$ was added and refluxed for 1 hr. After filtration, the filtrate was concentrated *in vacuo* and the residue was treated with petr. ether to give 57 mg. (79.6%) of the crystals, which was recrystallized from AcOEt-petr. ether to give colorless prisms, m.p. 100~101°. TLC 0.64. IR: nil $\nu_{NH}$. NMR: 7.03 ($-NCH_3$), 5.90 d ($-CH_2-$), 5.30 ($-NCH_2-$), 2.80 t (=CH), 2.72 $\tau$ ($C_6H_5$). *Anal.* Calcd. for $C_{15}H_{18}O_3N_2$: C, 65.67; H, 6.61; N, 10.21. Found: C, 65.12; H, 6.69; N, 10.32.

The authors are grateful to Prof. M. Tomita, Prof. S. Uyeo of Kyoto University, and Dr. K. Takeda, Director of this laboratory, for their encouragement throughout this work. The authors are also indebted to Dr. K. Tori and Messrs. I. Tanaka, M. Takasuga and K. Aono for the measurements of NMR, UV. and IR spectra, to the members of Analysis Room of this laboratory for elemental analyses, and to Mr. T. Ishiba for his technical assistance.

## Summary

The acid catalyzed condensation reactions of N-substituted ureas with enolether ester (I) or nitrile (II) were carried out, and the condensation products were isolated and those structures were confirmed. Alkylation of ethyl 2-oxo-1,2,3,4-tetrahydro-5-pyrimidinecarboxylate (XXI) afforded N-substituted tetrahydropyrimidines. Dehydrogenation of these N-substituted tetrahydropyrimidines gave N-substituted dihydropyrimidines readily.

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*UDC 547.831.7.07*

# 194. Yasuo Makisumi: The Claisen Rearrangement in Aromatic Heterocyclic Compounds. II.*1 The Thermal Rearrangement of Allyl 4-Quinolyl Ethers.

(*Shionogi Research Laboratory, Shionogi & Co., Ltd.**2)

In the preceding paper,*1 it was reported that the thermal rearrangement of allyl 2-methyl-4-quinolyl ethers affords the *ortho*-Claisen rearrangement products in about 90% yields along with their consecutive intramolecular cyclization products, the 2,3-dihydrofuro[3,2-*c*]quinoline derivatives. This reaction is unique in that rearrangement of an allyl group to an *ortho*-carbon atom takes place when the possibility for rearrangement[1] to a ring nitrogen atom also exists. It was of interest to determine whether rearrangement of allyl 4-quinolyl ethers would give a mixture of rearrangement products to the *ortho*-carbon and *para*-nitrogen atoms such as had been obtained from 5-methyl-7-allyloxy-*s*-triazolo[1,5-*a*]pyrimidine,[2] or whether exclusive rearrangement to the *ortho*-carbon atom would occur such as in the preceding work on allyl 2-methyl-4-quinolyl ethers.

For this purpose, allyl, methallyl, and crotyl ethers (Ia, Ib, and Ic) of 4-quinolinol were prepared by treatment of 4-chloroquinoline with sodium allyloxide, methallyloxide,

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*1 Part I. Y. Makisumi: This Bulletin, **12**, 789 (1964).

*2 Fukushima-ku, Osaka (牧角徳夫).

1) M. Conrad, L. Limpach: Ber., **20**, 948 (1887); M. Conrad, Fr. Eckhardt: *Ibid.*, **22**, 73 (1889); H. Meyer: Monatsh., **27**, 259, 265 (1906).

2) Y. Makisumi: This Bulletin, **11**, 851 (1963).

and crotyloxide in the corresponding alcohol under reflux. When Ia was heated at 200° without solvent, an exothermic reaction accompanying some extent of polymerization occurred. So, rearrangement of these ethers was undertaken by using 1-methylnaphthalene as a reaction solvent. Rearrangement of Ia at 200° in 1-methylnaphthalene afforded approximately a 93% yield of 3-allyl-4-quinolinol (IIa) as crystals insoluble in 1-methylnaphthalene. Analogous rearrangement of Ib gave a 65% yield of 3-methallyl-4-quinolinol (IIb). The crotyl ether (Ic) afforded a 91% yield of 3-(1-methylallyl)-4-quinolinol (IIc) resulting from inversion of the allylic group, which indicated that the rearrangement to the C-3 atom is a normal intramolecular Claisen rearrangement.

The structure of these rearrangement products was confirmed by ultraviolet and infrared spectra. IIa, b, c showed absorption curves characteristic for the 4(1*H*)-quinolone nucleus in the ultraviolet spectrum*[3] (see Fig. 1 and Table I) and the absorption bands of the NH group and the lactam carbonyl group in the infrared spectrum.*[3] Moreover, the CH out-of-plane deformation vibration of the $-CH=CH_2$ group appeared in the spectra of IIa and IIc and that of the $>C=CH_2$ group was shown in the spectrum of IIb. In order to determine the position to which the migrating allylic group is attached, the following experiments were attempted. The rearrangement products (IIa, b, c) were converted by chlorination with phosphoryl chloride into the corresponding 4-chloro derivatives (VIIa, VIIb, and VIIc), which exhibited the singlet signal peaks at 1.30, 1.31, and 1.23 $\tau$, respectively, due to the proton attached to the C-2

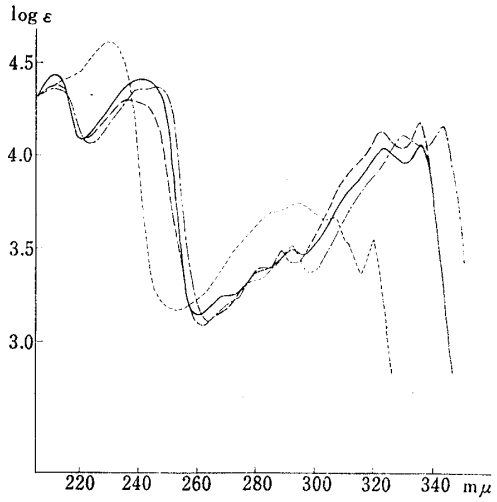



Fig. 1. Ultraviolet Absorption Spectra in Ethanol

——— IIa — — — IVa
– – – – – IIIa —•—•— Va

Table I. Ultraviolet Absorption Spectra (in EtOH)

| Compd. No. | $\lambda_{max}$ mμ (log ε) | | | | | |
|---|---|---|---|---|---|---|
| IIa | 212 (4.46) | 238 (4.42)[a] | 242 (4.43) | 291 (3.49) | 323 (4.05) | 336.5 (4.08) |
| IIb | 212 (4.46) | 238 (4.37)[a] | 242.5 (4.38) | 292 (3.55) | 323 (4.04) | 337 (4.08) |
| IIc | 211.5 (4.49) | 238 (4.44)[a] | 242.5 (4.45) | 290.5 (3.53) | 323 (4.06) | 336 (4.09) |
| IVa | 212 (4.40) | 237.5 (4.33) | 242 (4.30)[a] | 289 (3.47) | 323 (4.15) | 336.5 (4.21) |
| IVb | 210.5 (4.40) | 238.5 (4.32) | 242.5 (4.29)[a] | 289 (3.47) | 323.5 (4.15) | 337 (4.21) |
| IVc | 211 (4.41) | 238 (4.32) | 242.5 (4.30)[a] | 289.5 (3.51) | 323 (4.12) | 336.5 (4.21) |
| Va | 213 (4.39) | 241.5 (4.39)[a] | 245.5 (4.40) | 292.5 (3.51) | 330 (4.11) | 344 (4.18) |
| Vb | 212 (4.40) | 242.5 (4.36)[a] | 245.5 (4.37) | 292.5 (3.51) | 330 (4.11) | 344 (4.17) |
| Vc | 212 (4.45) | 242.5 (4.41)[a] | 245.5 (4.42) | 293 (3.55) | 331.5 (4.13) | 345 (4.18) |
| IIIa | 213.5 (4.44)[a] | 229.5 (4.69) | 294.5 (3.78) | 306 (3.71) | 319.5 (3.58) | |
| IIIb | 213.5 (4.42)[a] | 230 (4.64) | 294.5 (3.77) | 306 (3.71) | 319.5 (3.60) | |
| IIIc | 213.5 (4.46)[a] | 230 (4.70) | 294 (3.78) | 305.5 (3.71) | 319 (3.54) | |

*a*) shoulder

*[3] Although the 4-quinolinols can exist in either the lactim of lactam form, it is generally known by ultraviolet and infrared spectral studies*[1,3,4] that these compounds show the latter form in a neutral medium and solid state.

3) G. W. Ewing, E. A. Steck: J. Am. Chem. Soc., 68, 2181 (1946).
4) A. R. Katritzky: "Physical Methods in Heterocyclic Chemistry," II, 263 (1963), Academic Press, New York and London and references cited therein.

atom in their nuclear magnetic resonance spectra. Refluxing IIa, IIb, and IIc with hydrobromic acid in glacial acetic acid afforded their cyclization products, 2-methyl, 2,2-dimethyl-, and 2,3-dimethyl-2,3-dihydrofuro[3,2-*c*]quinolines(IIIa, IIIb, and IIIc) in good yields, respectively. These products exhibited absorption curves corresponding to those of the 2,3-dihydrofuro[3,2-*c*]quinoline derivatives*[1] in the ultraviolet region and showed the presence of the ether linkage and the absence of the NH, carbonyl, and methylene groups in the infrared region. The nuclear magnetic resonance spectra of these compounds substantiated the above assigned 2,3-dihydrofuro[3,2-*c*]quinoline structures as illustrated in Fig. 2. Thus, it was established that the rearrangement products (IIa, b, c) are normal *ortho*-Claisen rearrangement products to the C-3 atom.

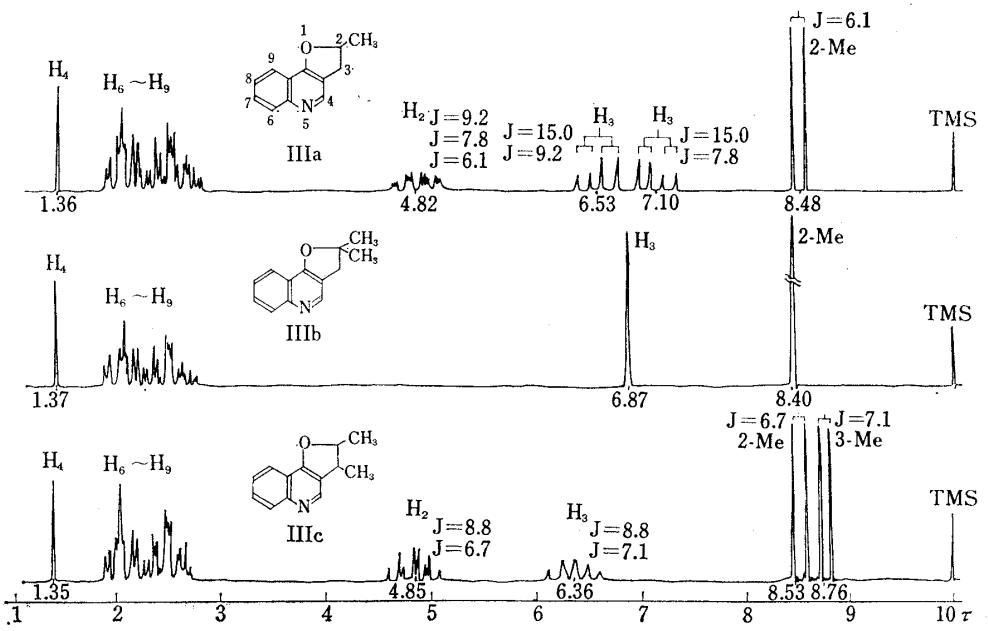



Fig. 2. Nuclear Magnetic Resonance Spectra of 2,3-Dihydrofuro[3,2-*c*]quinolines, at 60 Mc.p.s., in about 10% Solution in Deuteriochloroform

To determine the composition of the remainder of the reaction mixture, the residues from rearrangement of Ia, Ib, and Ic were investigated. A basic fraction isolated from the residue of the rearrangement of Ia, was subjected to alumina chromatography to give 2-methyl-2,3-dihydrofuro[3,2-*c*]quinoline (IIIa), 1-allyl-4(1*H*)-quinolone (IVa), 1,3-diallyl-4(1*H*)-quinolone (Va), and 4-quinolinol (VI) in about 0.3, 0.2, 0.2, and 0.2% yields, respectively. IIIa obtained from the rearrangement, was identical with 2-methyl-2,3-dihydrofuro[3,2-*c*]quinoline prepared by cyclization of IIa and VI was also identical with an authentic specimen of 4-quinolinol by infrared spectral comparison and mixed melting point determination. The structure of IVa and Va was assigned from the results of the elemental analysis of their picrates and the infrared and ultraviolet spectral analysis. These products showed the presence of the carbonyl group at 1630 $cm^{-1}$ and the absence of a NH group in the infrared region and exhibited absorption curves characteristic for the 4(1*H*)-quinolone nucleus in the ultraviolet region as shown in Table I. Similarly, the residue of the rearrangement of Ib afforded 2,2-dimethyl-2,3-dihydrofuro[3,2-*c*]quinoline (IIIb), 1-methallyl-4(1*H*)-quinolone (IVb), 1,3-dimethallyl-4(1*H*)-quinolone (Vb), and VI in about 31.5%, 0.3%, 0.2%, and 0.2% yields, respectively, and that of Ic gave 2,3-dimethyl-2,3-dihydrofuro[3,2-*c*]quinoline (IIIc), 1-crotyl-4(1*H*)-quinolone (IVc), 1-crotyl-3-(1-methylallyl)-4(1*H*)-quinolone (Vc), and VI in about 0.4, 0.3, 0.2, and 0.2% yields, respectively. IIIb and IIIc from the rearrangement reaction were identical with the 2,3-dihydrofuro[3,2-*c*]quinoline derivatives (IIIb and IIIc) prepared by cyclization of the Claisen rearrangement products (IIIb and IIc), respectively.

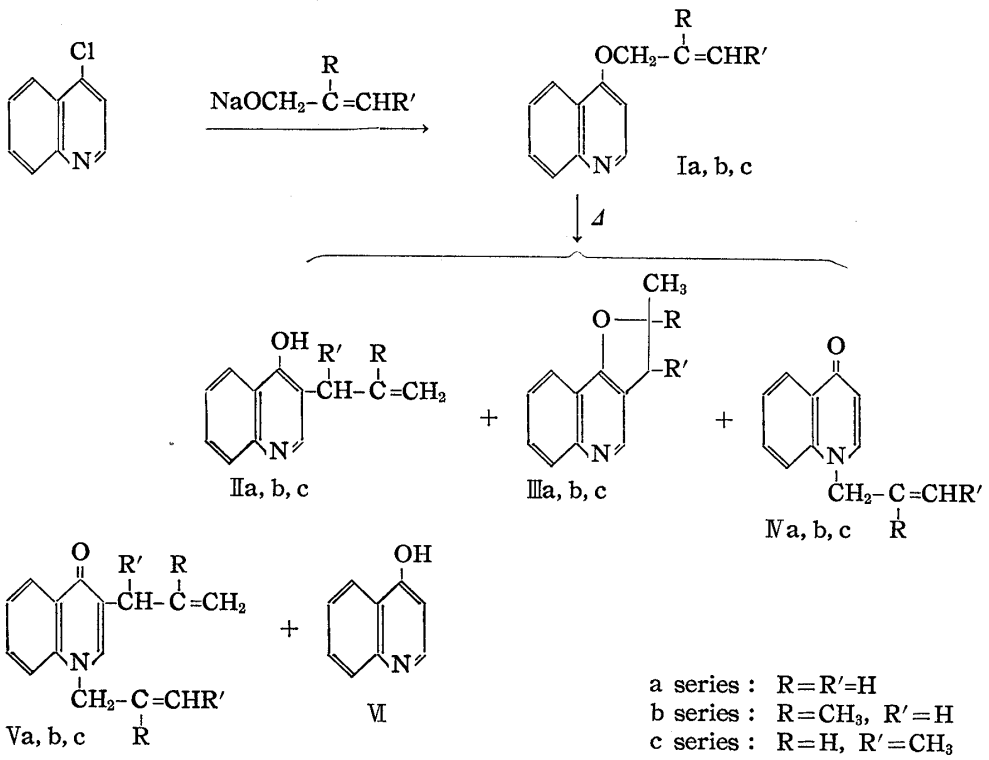
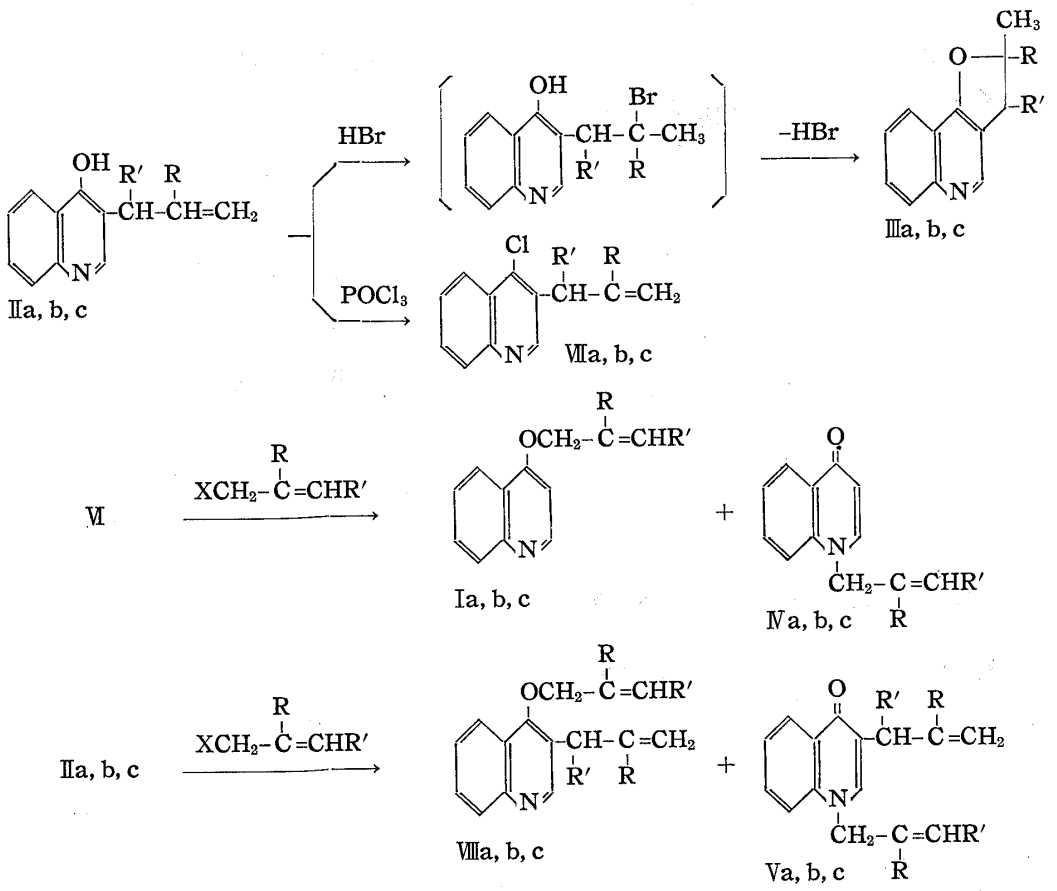



Chart 1.

In order to synthesize authentic samples of these N-allylic derivatives (IVa, b, c and Va, b, c), alkylation of 4-quinolinol (VI) and its 3-allylic derivatives (IIa, b, c) was undertaken. Reaction of VI with allylic halides in boiling ethanol in the presence of sodium ethoxide resulted in the formation of two kinds of alkylated products, which were separated by alumina chromatography to the O-allylic and N-allylic derivatives in the ratio of about 1:2. The structure of these products was confirmed by the infrared spectrum (the presence or absence of an absorption band due to the carbonyl group) and the ultraviolet spectrum (the absorption shapes of the both products, allylic ethers and N-allylic compounds). Reaction of VI with allyl bromide gave Ia and 1-allyl-4(1*H*)-quinolone and the latter was identical with IVa obtained from rearrangement of Ia by infrared spectral comparison and mixed melting point of the picrates of both samples. Similarly, 1-methallyl- and 1-crotyl-4(1*H*)-quinolones were obtained by the reaction of VI with methallyl chloride and crotyl bromide. These products were identical with the rearrangement products (IVb and IVc) respectively. Reaction of IIa with allyl bromide in boiling ethanol in the presence of sodium ethoxide afforded 3-allyl-4-allyloxyquinoline (VIIa) and 1,3-diallyl-4(1*H*)-quinolone (Va) in the ratio of 1:3. The latter was identical with the rearrangement product (Va) by infrared spectra. Analogously, the reaction of IIb with methallyl chloride gave 3-methallyl-4-methallyloxyquinoline (VIIb) and 1,3-dimethallyl-4(1*H*)-quinolone (Vb) and reaction of IIc with crotyl bromide afforded 3-(1-methylallyl)-4-crotyloxyquinoline (VIIc) and 1-crotyl-3-(1-methylallyl)-4(1*H*)-quinolone (Vc). These N-allylic products were identical with the products (Vb and Vc) obtained from the rearrangement reaction of the ethers (Ib and Ic) respectivly.

Neat rearrangement of the ethers (Ia, Ib, and Ic) took place at about 200°*4 and afforded the same products as were obtained upon rearrangement in 1-methylnaphthalene.

*4 As neat rearrangement of the ethers occurs exothermically, the inner temperature was carefully controlled at about 200°.



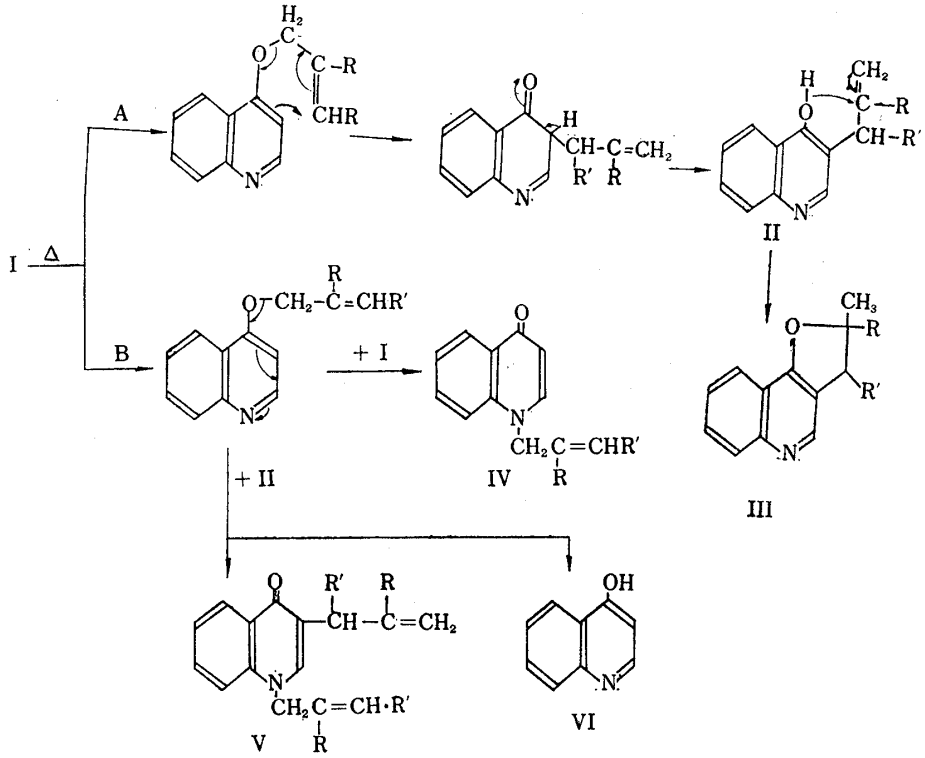
a series : R=R'=H b series : R=$CH_3$, R'=H c series : R=H, R'=$CH_3$

Chart 2.

Thus, it was evident that the thermal rearrangement of allyl 4-quinolyl ethers results in the formation of two types of the rearrangement products by the migration of the allyl group to the *ortho*-carbon atom (*ortho*-Claisen rearrangemant) and to the *para*-ring nitrogen atom (lactim ether-lactam isomerization). Treatment of these products under the rearrangement conditions demonstrated that they are thermodynamically stable, except a partial transformation of the Claisen rearrangement products (IIa, b, c) into their cyclization products, the 2,3-dihydrofuro[3,2-*c*]quinoline derivatives (IIIa, b, c). This result signifies that the 3-allylic compouds (IIa, b, c) and the N-allylic compounds (IVa, b, c) were produced from the ethers (Ia, b, c) by competitive rearrangements of the allylic group from the oxygen to the *ortho*-carbon atom and to the *para*-ring nitrogen atom and that the 2,3-dihydrofuro[3,2-*c*]quinoline derivatives (IIIa, b, c) were consecutively formed by intramolecular cyclization of IIa, b, c during these rearrangement reactions. Since it has been established that the *ortho*-Claisen rearrangement is the intramolecular reaction involving a six-membered cyclic transition state, the formation of compatible amounts of 1,3-diallylic compounds (Va, b, c) and 4-quinolinol (VI) in the rearrangement reaction of the allyl ethers demonstrates that the migration of the allyl group to the *para*-ring nitrogen atom must be an intermolecular reaction which proceeds by a mechanism involving homolytic or heterolytic cleavage of the ether bond.

Preceding work*[1] on the thermal rearrangement of allyl 2-methyl-4-quinolyl ethers indicated that only the *ortho*-Claisen rearrangement occurs and the lactim ether-lactam isomerization is not detectable.

It is evident that Claisen rearrangement involving an intramolecular cyclic transition state proceeds by very small activation energy in comparison with an intermolecular



A : *ortho*-Claisen rearrangement (intramolecular)
B : Lactim ether-lactam isomerization (concerted intermolecular)

Chart 3.

rearrangement involving the cleavage of an ether bond. Therefore, a facility of the cleavage of the ether bond between 4-quinolyl and 2-methyl-4-quinolyl ethers would bring different results.*[5] As the polar effect of the ring nitrogen is compensated somewhat by an inductive effect of the methyl group at the 2-position in the quinaldine derivative, an ether cleavage of allyl 2-methyl-4-quinolyl ethers may be more difficult than that of allyl-4-quinolyl ethers. Accordingly, rearrangement of allyl 2-methyl-4-quinolyl ethers would exclusively afford the *ortho*-Claisen rearrangement products. Such effect of the methyl group at the 2-position in quinoline system is also observed in nucleophilic substitution of 4-chloroquinaldine. Namely, although the chlorine atom of 4-chloroquinoline is relatively easily substituted by some nucleophilic reagents, the nucleophilic substitution of 4-chloroquinaldine is unexpectedly difficult.

## Experimental*[6]

**4-Allyloxyquinoline (Ia)**——To a solution of 3.53 g. (0.15 atom) of Na in 90 ml. of allyl alcohol, 16.35 g. (0.1 mol.) of 4-chloroquinoline was added, and the mixture was refluxed for 5 hr. After cooling, the precipitated NaCl was filtered off and the filtrate was evaporated under reduced pressure. The residue was dissolved in $Et_2O$, and the solution was washed with $H_2O$ and dried over $MgSO_4$. Evaporation of the solvent gave 17.9 g. of an oil, which was distilled to afford 17.1 g. of a colorless oil, $b.p_{0.9}$ 135°. On standing at room temperature the oil solidified to colorless pillars, m.p. 42°. *Anal.* Calcd. for $C_{12}H_{11}ON$ : C, 77.81; H, 5.99; N, 7.56. Found : C, 77.95; H, 6.21; N, 7.37. IR $\nu_{max}^{CHCl_3}$ $cm^{-1}$ : 1017 (-O-), 983, 930

*[5] Although a driving force in the lactim ether-lactam isomerizatin is considered to be the polar effect of the ring nitrogen on the ether cleavage, the steric interaction of the methyl group at the 2-position towards the bond formation between the allylic group and the ring nitrogen would also hinder the isomerization in 4-quinaldyl ethers.

*[6] All melting points were determined by a micro-melting point apparatus (Yanagimoto Co., Ltd., Kyoto) and are uncorrected. NMR spectra were measured in $CDCl_3$ with a Varian A-60 spectrometer at 60 Mc. using tetramethylsilane as an internal standard.

(-CH=CH$_2$). UV $\lambda_{max}^{EtOH}$ mμ (log ε) : 224 (4.81), 278 (3.85, sh*[7]), 285.5 (3.87), 299.5 (3.59, sh). It gave a picrate of yellow pillars, m.p. 213~213.5° from EtOH. *Anal.* Calcd. for $C_{12}H_{11}ON \cdot C_6H_3O_7N_3$ : C, 52.18; H, 3.41; N, 13.52. Found : C, 52.39; H, 3.56; N, 13.50.

**4-Methallyloxyquinoline (Ib)**——To a solution of 1.7 g. of Na in 40 ml. of methallyl alcohol, 8.1 g. of 4-chloroquinoline was added, and the mixture was treated as above to give 8.8 g. of an oil. Distillation of this oil afforded 8.46 g. of a colorless oil, b.$p_{0.04}$ 110~111°. *Anal.* Calcd. for $C_{13}H_{13}ON$ : C, 78.36; H, 6.58; N, 7.03. Found : C, 78.21; H, 6.70; N, 7.29. IR $\nu_{max}^{CHCl_3}$ cm$^{-1}$ : 1017 (-O-), 905 (>C=CH$_2$). UV $\lambda_{max}^{EtOH}$ mμ (log ε) : 224 (4.78), 277.5 (3.91, sh), 285.5 (3.92), 299 (3.66, sh), 304 (3.44, sh). It gave a picrate of yellow pillars, m.p. 214~215°, from EtOH. *Anal.* Calcd. for $C_{13}H_{13}ON \cdot C_6H_3O_7N_3$ : C, 53.27; H, 3.77; N, 13.08. Found : C, 53.19; H, 4.02; N, 13.22.

**4-Crotyloxyquinoline (Ic)**——To a solution of 1.1 g. of Na in 40 ml. of crotyl alcohol, 6.54 g. of 4-chloroquinoline was added, and the mixture was treated as above to afford 7.46 g. of an oil. Distillation of this oil gave 7.15 g. of a colorless oil, b.$p_{0.8}$ 136~137°. *Anal.* Calcd. for $C_{13}H_{13}ON$ : C, 78.36; H, 6.58; N, 7.03. Found : C, 78.19; H, 6.65; N, 7.01. IR $\nu_{max}^{CHCl_3}$ cm$^{-1}$ : 1017 (-O-), 966 (-CH=CH-). UV $\lambda_{max}^{EtOH}$ mμ (log ε) : 224 (4.79), 277 (3.86, sh), 285.5 (3.88), 298.5 (3.62, sh), 304 (3.43, sh). It gave a picrate of yellow scales, m.p. 197°, from EtOH. *Anal.* Calcd. for $C_{13}H_{13}ON \cdot C_6H_3O_7N_3$ : C, 53.27; H, 3.77; N, 13.08. Found : C, 53.37; H, 3.99; N, 13.27.

**Rearrangement of 4-Allyloxyquinoline (Ia) in 1-Methylnaphthalene**——A solution of 5.00 g. of Ia in 10 ml. of 1-methylnaphthalene was heated at 200° (inner temperature) for 1.5 hr. Upon cooling, 4.65 g. of 3-allyl-4-quinolinol (IIa) was precipitated from solution and collected by filtration. Recrystallization from aq. EtOH gave colorless scales, m.p. 185~187°. *Anal.* Calcd. for $C_{12}H_{11}ON$ : C, 77.81; H, 5.99; N, 7.56. Found : C, 77.73; H, 6.12; N, 7.67. IR $\nu_{max}^{Nujol}$ cm$^{-1}$ : 3225 (NH), 1634 (C=O), 1002, 911 (-CH=CH$_2$). UV : see Table I. The filtrate was dissolved in $Et_2O$ and the ethereal solution was extracted with 5% HCl. The HCl extract was washed with $Et_2O$, neutralized with $Na_2CO_3$, and extracted with $CHCl_3$. The $CHCl_3$ extract was washed with $H_2O$, dried over $MgSO_4$, and evaporated to afford 310 mg. of a pale brown oil. This oil was chromatographed on alumina and eluted with benzene, benzene-$CHCl_3$ (1:1), $CHCl_3$, AcOEt, and AcOEt-MeOH. Thin-layer chromatography was run on alternate fractions. When the same fractions were combined and solvents removed under reduced pressure, the residue was found to have the following composition with the components listed in order of elution (identifications are based on the comparison of their IR spectra with those of authentic compounds).

| | | |
|---|---|---|
| Fraction 1 | 4-Allyloxyquinoline (Ia) | 5 mg. |
| Fraction 2 | 2-Methyl-2,3-dihydrofuro[3,2-*c*]quinoline (IIIa) | 15 mg. |
| Fraction 3 | 1,3-Diallyl-4(1*H*)-quinolone (Va) | 18 mg. |
| Fraction 4 | 1-Allyl-4(1*H*)-quinolone (IVa) | 16 mg. |
| Fraction 5 | 3-Allyl-4-quinolinol (IIa) | 26 mg. |
| Fraction 6 | 4-Quinolinol (VI) | 8 mg. |

**Rearrangement of 4-Methallyloxyquinoline (Ib) in 1-Methylnaphthalene**——A solution of 5.00 g. of Ib in 10 ml. of 1-methylnaphthalene heated at 200° (inner temperature) for 1.5 hr., and the reaction mixture was diluted with $Et_2O$. The precipitated crystals were collected by filtration and washed with $Et_2O$ to give 3.25 g. of 3-methallyl-4-quinolinol (IIb). Recrystallization from aq. $Me_2CO$ afforded colorless needles, m.p. 155~156°. *Anal.* Calcd. for $C_{13}H_{13}ON$ : C, 78.36; H, 6.58; N, 7.03. Found : C, 78.22; H, 6.82; N, 7.06. IR $\nu_{max}^{Nujol}$ cm$^{-1}$ : 3226 (NH), 1621 (C=O), 886 (>C=CH$_2$). UV : see Table I. The filtrate and the washing solution were combined and extracted with 5% HCl. The extract was treated as above to give the following products.

| | | |
|---|---|---|
| Fraction 1 | 4-Methallyloxyquinoline (Ib) | trace |
| Fraction 2 | 2,2-Dimethyl-2,3-dihydrofuro[3,2-*c*]quinoline (IIIb) | 1.58 g. |
| Fraction 3 | 1,3-Dimethallyl-4(1*H*)-quinolone (Vb) | 12 mg. |
| Fraction 4 | 1-Methallyl-4(1*H*)-quinolone (IVb) | 16 mg. |
| Fraction 5 | 3-Methallyl-4-quinolinol (IIb) | 25 mg. |
| Fraction 6 | 4-Quinolinol (VI) | 7 mg. |

**Rearrangement of 4-Crotyloxyquinoline (Ic) in 1-Methylnaphthalene**——A solution of 5.00 g. of Ic in 10 ml. of 1-methylnaphthalene was heated at 200° (inner temperature) for 1.5 hr., and the reaction mixture was diluted with $Et_2O$-petr. benzin. The precipitated crystals were collected by filtration and washed with $Et_2O$ to afford 4.55 g. of 3-(1-methylallyl)-4-quinolinol (IIc). Recrystallization from benzene petr. benzin gave colorless prisms, m.p. 169~170°. *Anal.* Calcd. for $C_{13}H_{13}ON$ : C, 78.36; H, 6.58; N, 7.03. Found : C, 78.45; H, 6.63; N, 6.86. IR $\nu_{max}^{Nujol}$ cm$^{-1}$ : 3229 (NH), 1634 (C=O), 986, 905 (-CH=CH$_2$). UV : see Table I. The filtrate and the washing solution were combined and extracted with 5% HCl. The extract was treated as above to give the following fractions.

*[7] sh=shoulder

| | | |
|---|---|---|
| Fraction 1 | 4-Crotyloxyquinoline (Ic) | trace |
| Fraction 2 | 2,3-Dimethyl-2,3-dihydrofuro[3,2-*c*]quinoline (IIIc) | 17 mg. |
| Fraction 3 | 1-Crotyl-3-(1-methylallyl)-4(1*H*)-quinolone (Vc) | 18 mg. |
| Fraction 4 | 1-Crotyl-4(1*H*)-quinolone (IVc) | 16 mg. |
| Fraction 5 | 3-(1-Methylallyl)-4-quinolinol (IIc) | 76 mg. |
| Fraction 6 | 4-Quinolinol (VI) | 9 mg. |

**Neat Rearrangement of 4-Allyloxyquinoline (Ia), 4-Methallyloxyquinoline (Ib), and 4-Crotyloxyquinoline (Ic)**——Freshly distilled samples of the ethers were heated at 1 hr. and the inner temperature was controlled at about 200°. The reaction mixtures were treated with $Et_2O$-petr. benzin and the precipitated crystals were collected by filtration to give 3-substituted-4-quinolinols (IIa 89% yield, IIb 86% yield, and IIc 62% yield). The filtrate was subjected to alumina chromatography. The same components and a similar composition of their components as those obtained from rearrangements of the ethers in 1-methylnaphthalene were confirmed.

**3-Allyl-4-chloroquinoline (VIIa)**——A mixture of 2.0 g. of 3-allyl-4-quinolinol (IIa) and 8 ml. of $POCl_3$ was refluxed for 2 hr., and the excess of $POCl_3$ was removed under reduced pressure. The residual syrup was poured into ice-water and the solution made alkaline with NaOH. The precipitated oil was extracted with $Et_2O$. The extract was washed with $H_2O$, dried over $MgSO_4$, and evaporated to give 2.1 g. of a crude oil. Distillation of the oil gave a colorless oil, $b.p_{0.09}$ 101～102°. *Anal.* Calcd. for $C_{12}H_{10}NCl$: C, 70.76; H, 4.91; N, 6.88. Found: C, 70.92; H, 5.03; N, 6.86. NMR $\tau$: 1.30 ($H_2$), 1.73～2.33 ($H_5$-$H_8$), ～4.00 (-CH=), 4.78, 5.00 (=$CH_2$), 6.34 ($CH_2$).

**3-Methallyl-4-chloroquinoline (VIIb)**——A mixture of 1.0 g. of 3-methallyl-4-quinolinol (IIb) and 4 ml. of $POCl_3$ was treated as for the preparation of VIIa to give 1.05 g. of a crude oil. Distillation afforded a colorless oil, $b.p_{0.25}$ 120～121°. *Anal.* Calcd. for $C_{13}H_{12}NCl$: C, 71.27; H, 5.55; N, 6.43. Found: C, 71.58; H, 5.68; N, 6.47. NMR $\tau$: 1.31 ($H_2$), 1.75～2.68 ($H_5$-$H_8$), 5.14, 5.37 (=$CH_2$), 6.41 ($CH_2$), 8.25 ($CH_3$).

**3-(1-Methylallyl)-4-chloroquinoline (VIIc)**——A mixture of 1.0 g. of 3-(1-methylallyl)-4-quinolinol (IIc) and 4 ml. of $POCl_3$ was treated as for the preparation of VIIa to afford 1.07 g. of a crude oil. Distillation gave a colorless oil, $b.p_{0.1}$ 112～113°. *Anal.* Calcd. for $C_{13}H_{12}NCl$: C, 71.27; H, 5.55; N, 6.43. Found: C, 71.23; H, 5.69; N, 6.34. NMR $\tau$: 1.23 ($H_2$), 1.71～2.50 ($H_5$-$H_8$), 3.88 (-CH=), 4.74, 4.97 (=$CH_2$), 5.78 (-$CH<$), 8.54 ($CH_3$).

**2-Methyl-2,3-dihydrofuro[3,2-*c*]quinoline (IIIa)**——To a solution of 1.0 g. of IIa in 5 ml. of AcOH, 2 g. of 48% HBr was added, and the mixture was refluxed for 4 hr. After evaporation of the reaction mixture, the residue was dissolved in $H_2O$ and made alkaline with NaOH. The precipitated crystals were extracted with $Et_2O$ and the extract was washed with $H_2O$, dried over $MgSO_4$, and evaporated to give 930 mg. of crystals. Recrystallization from petr. benzin afforded colorless pillars, m.p. 69～70°. *Anal.* Calcd. for $C_{12}H_{11}ON$: C, 77.81; H, 5.99; N, 7.56. Found: C, 78.05; H, 6.12; N, 7.77. IR $\nu_{max}^{CHCl_3}$ $cm^{-1}$: 1082, 1037 (-O-). UV: see Table I. NMR: see Fig. 2.

**2,2-Dimethyl-2,3-dihydrofuro[3,2-*c*]quinoline (IIIb)**——This compound was prepared from IIb in quantitative yield by the procedure used for the preparation of IIIa. Recrystallization from petr. benzin gave colorless prisms, m.p. 80～81°. *Anal.* Calcd. for $C_{13}H_{13}ON$: C, 78.36; H, 6.58; N, 7.03. Found: C, 78.32; H, 6.60; N, 6.94. IR $\nu_{max}^{CHCl_3}$ $cm^{-1}$: 1084, 1024 (-O-). UV: see Table I. NMR: see Fig. 2.

**2,3-Dimethyl-2,3-dihydrofuro[3,2-*c*]quinoline (IIIc)**——This material was prepared from IIc in quantitative yield by the procedure used for the preparation of IIIa. Recrystallization from petr. benzin afforded colorless prisms, m.p. 100～102°. *Anal.* Calcd. for $C_{13}H_{13}ON$: C, 78.36; H, 6.58; N, 7.03. Found: C, 78.56; H, 6.85; N, 7.28. IR $\nu_{max}^{CHCl_3}$ $cm^{-1}$: 1093, 1022 (-O-). UV: see Table I. NMR: see Fig. 2.

**1-Allyl-4(1*H*)-quinolone (IVa) by Alkylation of 4-Quinolinol (VI)**——To a solution of 2.9 g. (0.02 mol.) of VI and EtONa (prepared from 0.505 g. (0.022 atom) of Na) in 40 ml. of abs. EtOH, 2.66 g. (0.022 mol.) of allyl bromide was added, and the mixture was refluxed for 5 hr. Precipitated NaBr was filtered off. The solvent was removed from the filtrate under reduced pressure. The residue was dissolved in $CHCl_3$ and the $CHCl_3$ solution was washed with aq. NaOH solution and $H_2O$. Evaporation of the solvent after drying gave 3.05 g. of a light tan oil, which was subjected to alumina chromatography to afford two fractions. The fraction eluted with benzene gave 0.86 g. (22%) of a colorless oil. Distillation gave colorless pillars, m.p. 42° ($b.p_{0.2}$ 113°), which were identical with 4-allyloxyquinoline (Ia) prepared from 4-chloroquinoline by IR spectral comparison. The fraction eluted with $CHCl_3$ gave 1.87 g. (48%) of 1-allyl-4(1*H*)-quinolone (IVa), which was distilled to afford a colorless oil, $b.p_{0.08}$ 170～172°. *Anal.* Calcd. for $C_{12}O_{11}ON$: C, 77.81; H, 5.99; N, 7.56. Found: C, 77.95; H, 6.21; N, 7.37. IR: $\nu_{max}^{CHCl_3}$ 1630 $cm^{-1}$. UV: see Table I. It gave a picrate of yellow pillars, m.p. 197～198° from EtOH. *Anal.* Calcd. for $C_{12}H_{11}ON \cdot C_6H_3O_7N_3$: C, 52.18; H, 3.41; N, 13.52. Found: C, 51.91; H, 3.52; N, 13.75.

**1-Methallyl-4(1*H*)-quinolone (IVb) by Alkylation of 4-Quinolinol (VI)**——To a solution of 1.45 g. (0.01 mol.) of VI and EtONa (prepared from 0.25 g. of Na) in 25 ml. of abs. EtOH, 1.0 g. of methallyl chloride was added, and the mixture was treated as for the preparation of IVa. The resulting oil (1.38 g.) was chromatographed on alumina and eluted with benzene and $CHCl_3$. The first fraction eluted with benzene

gave 400 mg. (20%) of a colorless oil, identical with 4-methallyloxyquinoline (Ic) by IR spectral comparison. The next fraction eluted with $CHCl_3$ afforded 920 mg. (46%) of Ⅳb, which was recrystallized from benzene-petr. benzin to give colorless plates, m.p. 68~69°. *Anal.* Calcd. for $C_{13}H_{13}ON \cdot H_2O$ : C, 71.86; H, 6.96; N, 6.46. Found : C, 72.11; H, 7.18; N, 6.45. IR $\nu_{max}^{Nujol}$ $cm^{-1}$ : 1623 (C=O), 898 (>C=$CH_2$). UV : see Table I.

**1-Crotyl-4(1*H*)-quinolone (IVc) by Alkylation of 4-Quinolinol (VI)**——A mixture of 1.45 g. of Ⅵ, 1.35 g. of crotyl bromide, and EtONa (prepared from 0.23 g. of Na) in 25 ml. of abs. EtOH was treated as for the preparation of Ⅳa and the resulting oil (1.69 g.) was subjected to alumina chromatography to afford two fractions. The first fraction eluted with benzene gave 600 mg. (25%) of an oil ($b.p_{0.2}$ 139~140°), identical with 4-crotyloxyquinoline (Ic) described above by IR spectral comparison. The next fraction eluted with $CHCl_3$ gave 1.04 g. (52%) of Ⅳc, which was distilled to afford a colorless oil, $b.p_{0.05}$ 165~166°. *Anal.* Calcd. for $C_{13}H_{13}ON$ : C, 78.36; H, 6.58; N, 7.03. Found : C, 78.39; H, 6.71; N, 7.01. IR $\nu_{max}^{CHCl_3}$ $cm^{-1}$ : 1628 (C=O), 965 (-CH=CH-). UV : see Table I.

**1,3-Diallyl-4(1*H*)-quinolone (Va) by Alkylation of 3-Allyl-4-quinolinol (IIa)**——A mixture of 1.85 g. (0.01 mol.) of Ⅱa, 1.21 g. of allyl bromide, and EtONa (prepared from 0.23 g. of Na) in 20 ml. of abs. EtOH was treated as for the preparation of Ⅳa, and the resulting oil (1.7 g.) was chromatographed on alumina. Elution with benzene gave 413 mg. (18.5%) of 3-allyl-4-allyloxyquinoline (Ⅷa) as a colorless oil. IR : lack of C=O. It gave a picrate of yellow pillars, m.p. 141~142°, from EtOH. *Anal.* Calcd. for $C_{15}H_{15}ON \cdot C_6H_3O_7N_3$ : C, 55.51; H, 3.99; N, 12.33. Found : C, 55.52; H, 4.12; N, 12.08. Elution with $CHCl_3$ afforded 1.27 g. (56.5%) of Va, which was distilled to give a colorless oil, $b.p_{0.4}$ 184~185°. *Anal.* Calcd. for $C_{15}H_{15}ON$ : C, 79.97; H, 6.71; N, 6.22. Found : C, 79.83; H, 6.85; N, 6.23. IR $\nu_{max}^{CHCl_3}$ $cm^{-1}$ : 1630 (C=O), 995, 921 (-CH=$CH_2$). UV : see Table I. It gave a picrate of yellow pillars, m.p. 116~117°, from EtOH. *Anal.* Calcd. for $C_{15}H_{15}ON \cdot C_6H_3O_7N_3$ : C, 55.51; H, 3.99; N, 12.33. Found : C, 55.77; H, 4.06; N, 12.47.

**1,3-Dimethallyl-4(1*H*)-quinolone (Vb) by Alkylation of 3-Methallyl-4-quinolinol (IIb)**——A mixture of 1.00 g. of Ⅱb, 460 mg. of methallyl chloride, and EtONa (prepared from 120 mg. of Na) in 15 ml. of abs. EtOH was treated as for the preparation of Ⅳa, and the resulting oil (990 mg.) was subjected to alumina chromatography. The fraction eluted with benzene gave 240 mg. (19%) of 3-methallyl-4-methallyloxyquinoline (Ⅷb) as a colorless oil. IR : lack of C=O. It gave a picrate of yellow pillars, m.p. 145~146°, from EtOH. *Anal.* Calcd. for $C_{17}H_{19}ON \cdot C_6H_3O_7N_3$ : C, 57.26; H, 4.60; N, 11.61. Found : C, 57.18; H, 4.63; N, 11.48. The fraction eluted with $CHCl_3$ afforded 730 mg. (58%) of Vb. Recrystallization from petr. benzin gave colorless pillars, m.p. 68~69°. *Anal.* Calcd. for $C_{17}H_{19}ON$ : C, 80.57; H, 7.56; N, 5.53. Found : C, 80.81; H, 7.69; N, 5.59. IR $\nu_{max}^{CHCl_3}$ $cm^{-1}$ : 1630 (C=O), 903 (>=$CH_2$). UV : see Table I.

**1-Crotyl-3-(1-methylallyl)-4(1*H*)-quinolone (Vc) by Alkylation of 3-(1-Methylallyl)-4-quinolinol (IIc)**——A mixture of 1.00 g. of Ⅱc, 680 mg. of crotyl bromide, and EtONa (prepared from 120 mg. of Na) in 15 ml. of abs. EtOH was treated as above, and the resulting oil (1.06 g.) was chromatographed on alumina. Elution with benzene gave 250 mg. (20%) of 3-(1-methylallyl)-4-crotyloxyquinoline (Ⅷc) as a colorless oil. IR : lack of C=O. It gave a picrate of yellow plates, m.p. 142~143°, from EtOH. *Anal.* Calcd. for $C_{17}H_{19}ON \cdot C_6H_3O_7N_3$ : C, 57.27; H, 4.60; N, 11.61. Found : C, 57.05; H, 4.80; N, 11.55. Elution with $CHCl_3$ afforded 760 mg. (60%) of Vc, which was distilled to give a colorless oil, $b.p_{0.01}$ 140~141°. *Anal.* Calcd. for $C_{17}H_{19}ON$ : C, 80.57; H, 7.56; N, 5.53. Found : C, 80.39; H, 7.71; N, 5.67. IR $\nu_{max}^{CHCl_3}$ $cm^{-1}$ : 1628 (C=O), 964 (-CH=CH-), 990, 916 (-CH=$CH_2$). UV : see Table I.

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## Summary

Thermal rearrangement of allyl 4-quinolyl ethers in 1-methylnaphthalene or without solvent resulted in the formation of good yields of the *ortho*-Claisen rearrangement products and small amounts of the lactim ether-lactam isomerization products (1-allyl-4(1*H*)-quinolones). A part of the Claisen rearrangement products were consecutively transformed into the 2,3-dihydrofuro[3,2-*c*]quinoline derivatives by their intramolecular cyclization in the process of this reaction. It was confirmed that the latter isomerization reaction is an intermolecular rearrangement.

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