β-D-oleandroside. Since cymaropyranose possesses only two hydroxy groups at C-1 and C-4, the sugar sequence in I has to be linear and is determined as shown in Chart 1.

We assigned ^{13}C signals of the sugar chain in I as shown in Table I in comparison with the data on ^{13}C chemical shifts of methyl β-D-cymaroside (V) and α,β-D-oleandroside (VII, IX).[6]

From ^{13}C chemical shifts of the anomeric carbon of V and VII, both D-cymarose and D-oleandrose moieties in I are suggested to have a β-configuration at C-1.

In order to confirm the sequence of sugar chain, acetylated cynanchoside C_2 (II) was hydrolyzed under acidic condition and afforded 4-*O*-acetyloleandrose (VIII), cymarose (IV), and cynanchogenin (III).

We have concluded the structure of cynanchoside C_2 to be cynanchogenin-3-*O*-β-D-oleandropyranosyl-(1→4)-β-D-cymaropyranosyl-(1→4)-β-D-cymaropyranoside (I).

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6) F. Abe and T. Yamauchi, *Chem. Pharm. Bull.* (Tokyo), **26**, 3023 (1978).

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Intermolecular Photochemical Cycloaddition of 4-Methoxy-2-quinolone with Olefins: A Regioselective Synthesis of 5-Substituted Cyclobuta[*c*]-2-quinolones

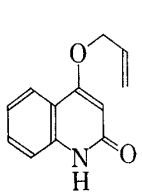
Irradiation of 4-methoxy-2-quinolone (IV) in methanol in the presence of substituted ethylenes provided intermolecular addition products. The cycloaddition reaction was shown to be regioselective giving in all cases 5-substituted 3,6-dihydrocyclobuta[*c*]-2-quinolones (V). Base treatment of these cycloadducts afforded the corresponding cyclobuta[*c*]-2-quinolones (VI).

Keywords——cyclobuta[*c*]-2-quinolones; 6-methoxyl-3,6-dihydrocyclobuta[*c*]-2-quinolones; regioselective 2+2 photocycloaddition; biradical intermediate in photochemical cycloaddition reaction; aza-analogs of benzocyclobutene

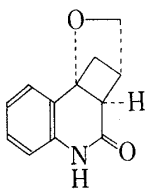
Recently, we reported that irradiation of 4-allyloxy-2-quinolones (*e.g.* I) produced intramolecular 2+2 cycloaddition products (*e.g.* II) and the successful transformation of the products to the so far unknown cyclobuta[*c*]-2-quinolones (*e.g.* III) by base treatment.[1] An ability of the 3,4-double bond in these quinolones to participate in an intramolecular photocycloaddition reaction seems to suggest that the same bond of 4-alkoxy-2-quinolone may likewise be susceptible to an intermolecular cycloaddition reaction with olefins, though the

1) C. Kaneko, T. Naito, and M. Somei, *J.C.S. Chem. Commun.*, **1979**, in press.

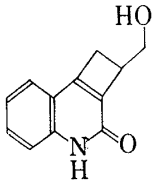
photodimerization reaction of 2-quinolones is known to occur only if they have no substituent at the 4-position.[2] Thus, it was of interest to investigate the photochemistry of 4-alkoxy-2-quinolone in the presence of olefins in order to obtain the 2+2 cycloadducts[3] and examine their subsequent transformation to cyclobuta[*c*]-2-quinolones. The experiment along this line has led us to find a general regioselective synthetic route to cyclobuta[*c*]-2-quinolones substituted at the 5-position.



I



II



III

Photolysis of 5 mM solution of 4-methoxy-2-quinolone[4] (IV) in methanol containing a 20—30 molar excess of isobutylene[5] yielded a cycloadduct (Va) in 80% yield as a sole product. The structure of Va was established on the basis of combustion analysis and ^{1}H-NMR spectra.[6] Thus, the C_3-proton appeared as a triplet (δ 3.3 with J=10 Hz) indicated clearly the head-to-tail structure. In the same manner, the 2+2 cycloadducts (Vb—d) were also obtained from the reactions with other olefins and the result is summarized in the Table.

Table I. Melting point of 5-Substituted Cyclobuta[*c*]-2-quinolones (VI) and Their 3,6-Dihydro Derivatives (V)

	X	V	VI
a	$-(CH_3)_2$	150—151°	197—198°
b	$-CH_2OAc$	174—175°	231—232° *a)*
c	$-CN$	210—213°	254—256° (dec)
d	$-COOCH_3$	227—229° (dec)	230—231° (dec) *b)*

a) X=CH_2OH. *b)* X=COOH.

Treatment of these adducts (Va—d) with base led to a novel and synthetically useful reaction. Reaction of Va with sodium methoxide in methanol at reflux for 2 hr afforded VIa in a quantitative yield. Under the same conditions, all of the other adducts also afforded 5-substituted cyclobuta[*c*]-2-quinolones (VIb—d) all in high yields. The structure of the products was supported by ^{1}H-NMR [δ for VIa: 1.56 (CH_3, s, 6H) and 2.98 (C_4–H, s, 2H)] and UV spectra showing the presence of carbostyril chromophore [λ_{max} nm (log ε) of VIa: 227 (4.57), 272 (3.82), 281 (3.79), 322 (3.92), 335 (3.81)].

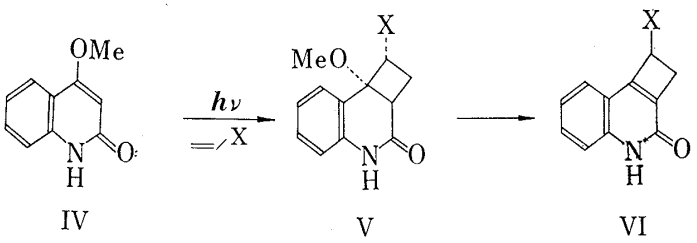
2) *a*) O. Buchardt, *Acta Chem. Scand.*, **18**, 1389 (1964); *b*) M. Ishikawa, S. Yamada, H. Hotta, and C. Kaneko, *Chem. Pharm. Bull.* (Tokyo), **14**, 1102 (1966).

3) Essentially similar photoadditions of 4-hydroxycoumarin and N-methyl-4-hydroxy-2-quinolone to cyclohexene were reported: R.G. Hunt, C.J. Potter, S.T. Reid, and M.L. Roantree, *Tetrahedron Lett.*, **1975**, 2327.

4) A convenient synthesis of 4-alkoxy-2-quinolone and its 1-methyl derivatives has been reported: C. Kaneko, T. Naito, M. Hashiba, H. Fujii, and M. Somei, *Chem. Pharm. Bull.* (Tokyo), **27**, 1813 (1979).

5) All irradiations were carried out under nitrogen with a Toshiba 400P high-pressure mercury lamp using a Pyrex filter ($\lambda \geq ca.$ 300 nm).

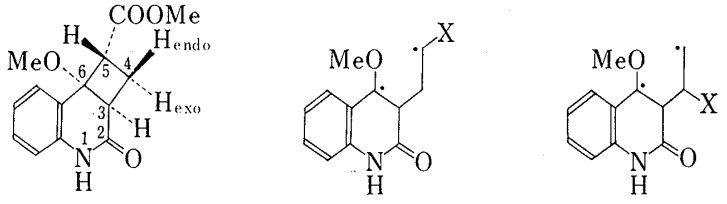
6) Satisfactory microanalyses, and mass and other spectral data were obtained for all new compounds. Unless otherwise noted, NMR spectra were recorded in $CDCl_3$ and UV in methanol. Melting points are uncorrected.



IV V VI

	X (V)	X (VI)
a	$-(CH_2)_2$	
b	$-CH_2OAc$	$-CH_2OH$
c	$-CN$	
d	$-COOCH_3$	$-COOH$

Assuming that *cis* vicinal coupling is larger than the *trans* one in a cyclobutane skeleton,[7] the stereochemistry of the adducts (Vb—d) can be tentatively assigned to have the *anti*-configuration.[8] For example, the NMR spectrum of Vd showed four cyclobutane hydrogens at δ 3.61 (d, d J=11 and 8 Hz: H-3), 3.38 (d, d J=3.5 and 8: H-5), 2.28 (d, t J=3.5 and 11: H-4_{exo}), and 1.99 (d, t J=11 and 8: H-4_{endo}) with $J_{3,4\text{-exo}}$=11 Hz, $J_{3,4\text{-endo}}$=8, $J_{4\text{-exo, }4\text{-endo}}$=11, $J_{5,4\text{-endo}}$=8, and $J_{5,4\text{-exo}}$=3.5.



Vd VII VIII

While concerted 2+2 cycloaddition mechanism[9] is not regally excluded at present, the origin of the regioselectivity in the formation of V could be reasonably explained by assuming the intermediacy of biradical such as VII, which should be more stable than the other one (VIII). Interestingly, Evanega *et al.* showed that photocycloaddition between 2-quinolone and olefins also proceeded stereoselectively to give only head-to-tail adducts.[10]

The present result extends the utility of 4-alkoxy-2-quinolone as a photochemical synthon for 5-substituted cyclobuta[*c*]-2-quinolones, aza-analogs of benzocyclobutene whose versatile utility in synthetic reactions is now well documented.[11]

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7) L.M. Jackman and S. Sternhell, "Applications of nuclear magnetic resonance spectroscopy in org. chem.," 2nd Ed., Pergamon Press, N.Y., 1969, p. 287 and refs cited.
8) If the adducts (Vb—d) had a *trans* ring juncture, treatment with base should give the thermodynamically more stable *cis* ring fused products. Since no isomerization was observed with these adducts under the condition for their conversion to VI, the supposition of *cis* ring fusion for Va—d seems to be secured.
9) K.N. Houk, "Pericyclic Reactions," Vol. 2, ed. by A.P. Marchand and R.E. Lehr, Academic Press, N.T., 1977, p. 233 and refs cited.
10) G.R. Evanega and D.L. Fabiny, *J. Org. Chem.*, **35**, 1757 (1970).
11) Upon pyrolysis, benzocyclobutene afforded a highly reactive *ortho*-quinodimethane, which reacted *in sutu* with dienophiles (*e.g.* olefins and imines) either intra- or intermolecularly to give polycyclic ring systems containing one benzene ring. See, W. Oppolzer, *Synthesis*, **1978**, 793; T. Kametani and K. Fukumoto, *Heterocycles*, **3**, 29 (1975).