CHEMISTRY LETTERS, pp. 727-730, 1985. © 1985 The Chemical Society of Japan

THE PHOTO-REARRANGEMENT OF HYPOIODITES GENERATED FROM CYCLOBUTANOLS FORMED BY MEANS OF 2+2 PHOTOCYCLOADDITION BETWEEN 4-HYDROXY-2-QUINOLONE AND CYCLOALKENE OR ALKENE TO 2,3-FURANOQUINOL-4-ONES$^{1)}$

Hiroshi SUGINOME,* Kazuhiro KOBAYASHI, Masahito ITOH, and Akio FURUSAKI†
Faculty of Engineering, Hokkaido University, Sapporo 060
† Department of Chemistry, Faculty of Science, Hokkaido University, Sapporo 060

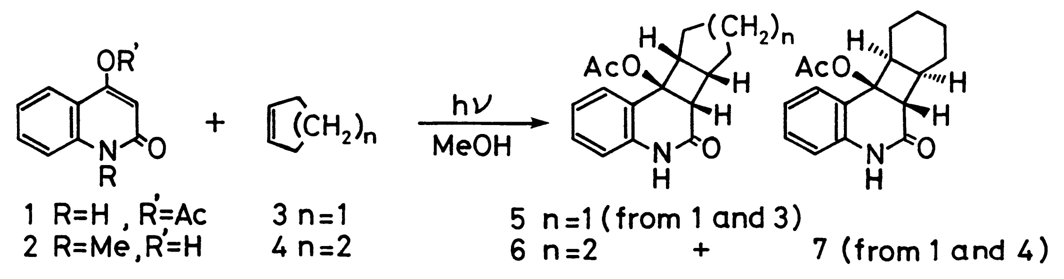
The irradiation of hypoiodites generated from cyclobutanols prepared by means of N-methylation and hydrolysis of 2+2 photocycloadducts between 4-acetoxy-2-quinolone and cyclopentene or 2,3-dimethylbut-2-ene induced rearrangements of the corresponding alkoxy radicals to give 2,3-furanoquinol-4-ones or a ring expanded product.

As part of our program to explore the potential of β-scission of alkoxy radicals for organic synthesis, we have recently studied the β-scission of alkoxy radicals generated from cyclobutanols (*e.g.*, 14) formed by 2+2 photocycloaddition$^{2)}$ between 4-hydroxycoumarin and cycloalkenes. We found that these alkoxy radicals (*e.g.*, 16) lead to the rearrangement to give furobenzopyron-5-ones (*e.g.*, 22) *via* a carbon-centered radical (*e.g.*, 19 or 21)$^{3)}$ (Scheme 1). Furthermore, we have shown that the irradiation of the hypoiodite of the adduct 26 formed by the photocycloaddition of 4-hydroxycoumarin with 2,3-dimethylbut-2-ene gives a 1:1 mixture of furobenzo-γ-pyrone 28 and furocoumarin 30.$^{4)}$

From the synthetic as well as the mechanistic points of views, it may be worth exploring the extension of the reaction to the cyclobutanols obtained by 2+2 photocycloaddition between 4-hydroxy-2-quinolone and alkenes and examining the effect of the ring hetero-atom. In this paper we wish to report the results of the photolysis of hypoiodites of the nitrogen analogues 11, 12, 13, and 27 for the oxacycloadducts 14 and 26. The results demonstrate that there are appreciable differences in the behavior of the alkoxy radicals when the ring oxygen of coumarin adducts (*e.g.*, 16) is replaced by a nitrogen atom (*e.g.*, 15).

The formation of photo-cycloadducts of 4-hydroxyquinol-2-one and its derivative with alkenes was first reported by Reid and his colleagues$^{5a)}$ and later by Kaneko and his colleagues.$^{5b)}$ The photochemical cycloadducts 11, 12, 13, and 27 for the present experiments were synthesized by means of a photochemical 2+2 cycloaddition of 4-acetoxyquinol-2-one (1) with cyclopentene (3), cyclohexene (4) or 2,3-dimethylbut-2-ene to give cycloadducts 5, 6, 7, and 25, followed by the methylation of their imino group and the hydrolysis of their acetoxy group.

The irradiation of 1 and cyclopentene (3) in methanol for 12 h in an atmosphere of a nitrogen with 400-W high pressure mercury arc through a



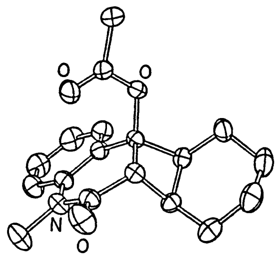
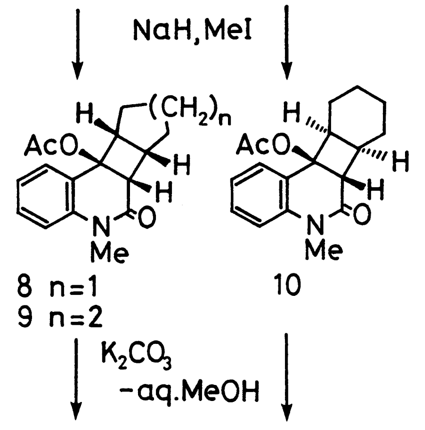
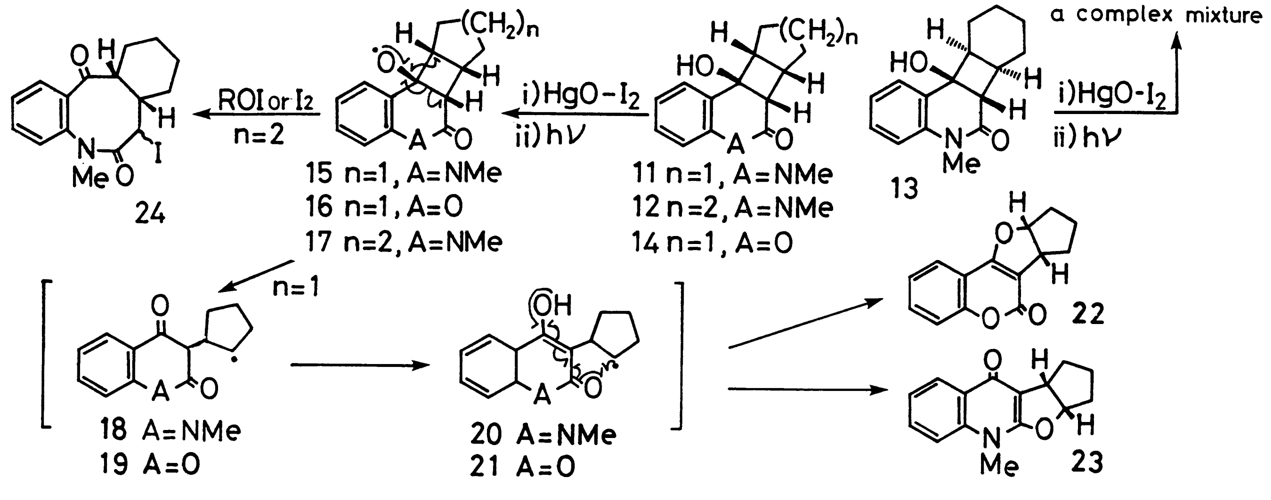
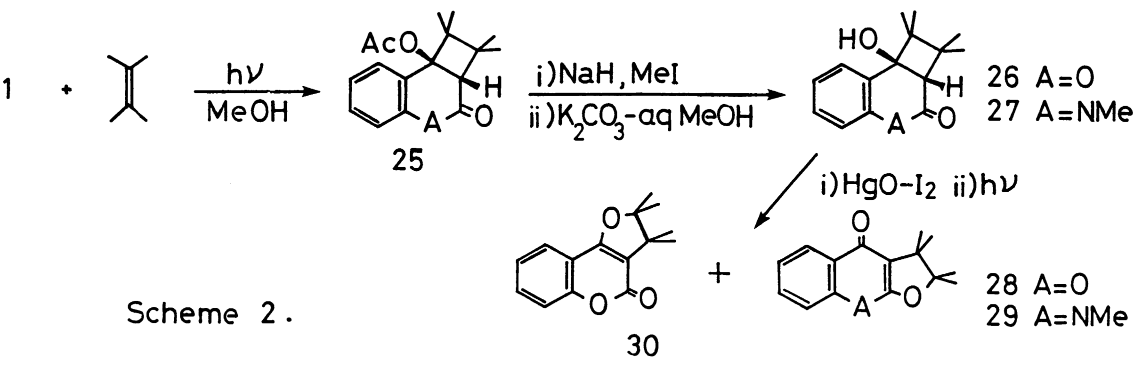


Fig. 1.
X-Ray structure for cycloadduct 7.





Scheme 1.



Scheme 2.

Pyrex filter gave a crystalline adduct 5[6] in 64% yield. A *cis*-*syn*-*cis* structure is assigned by a comparison of its ^{1}H NMR spectrum with that of the oxygen analogue 14 for which a *cis*-*syn*-*cis* structure was established by means of an X-ray crystallographic analysis.[2] The photocycloaddition of 1 with cyclohexene under similar conditions, on the other hand, led to the formation of two isomeric photocycloadducts 6[7] and 7[8] in 41 and 52% yields which were separable by TLC. A *cis*-*syn*-*cis* structure is assigned to 6 since its IR showed the carbonyl band at the wave-length very similar to those of 5[6] but defferent from 7. ^{1}H NMR spectrum of 6 and 7 indicated a doublet at δ 3.79 (*J*=8.79) and 3.37 (*J*=10.33) assignable to a proton attached to their carbon atom adjacent to the carbonyl. This suggested that 7 had a *cis*-*anti*-*cis* structure which was confirmed by its X-ray crystallographic analysis. The crystal data for 7 were as follows: $C_{18}H_{21}NO_3$, triclinic, space group P$\bar{1}$, a=9.664(2), b=9.711(2), c=0.305(2) Å, α=110.12(2), β=95.88(2), γ=71.36(2)^0, z=2, D_c=1.280 g cm^{-3}. The intensities of 3421 independent reflections with $2\theta<58°$ were obtained on a Rigaku four-circle diffractometer with graphite-monochromated Mo-Kα radiation using the ω-2θ scanning mode.[9] The structure was elucidated by the Monte Carlo direct method[4] using 15 reflections as the starting set, and refined by the block-diagonal least-squares method with anisotropic thermal parameters. A difference Fourier map revealed all the hydrogen atoms. The R value reached 0.048 by further refinements including the hydrogen atoms. The molecular framework thus obtained is shown in Fig. 1. The treatment of the adducts 5, 6, and 7 in DMF with NaH and then with methyl iodide gave the corresponding N-methyl derivatives 8,[11a] 9,[11b] and 10[11c] respectively in 81-98% yield.

Hydrolysis of the N-methyl derivatives with potassium carbonate in aq. methanol afforded the corresponding cyclobutanol 11,[11d] 12,[11e] and 13[11f] in 75, 52, and 81% yields respectively. The cycloadducts 12 and 13 can also be prepared directly[5] by means of the photoaddition of 4-hydroxy-N-methylquinol-2-one (2) with cyclohexene but in only 34% yield in total.[12] Finally, the irradiation of 1 with 2,3-dimethylbut-2-ene as a representative alkene gave cycloadduct 25[13] in a rather poor yield (11%). The N-methylation of 25 followed by the hydrolysis gave a crystalline cyclobutanol 27[14] in a high overall yield (Scheme 2).

Irradiation of cyclobutanol 11 (84 mg) in benzene (10 ml) containing mercury (II) oxide (216 mg) and iodine (254 mg) in a Pyrex vessel with a 100-W Hg arc lamp for 6 h under a nitrogen atmosphere gave a crystalline product 23[15] in a 21% isolated yield. The molecular formula of 23 was established as $C_{15}H_{15}NO_2$ by high resolution mass spectrometry and the structure was assigned to be a 2,3-furoquinol-4-one 23. Photolysis of cyclobutanol 27 under similar conditions also gave a 2,3-furoquinol-4-one 29[16] exclusively in high isolated yield (63%) (Scheme 2).

In contrast to the photolysis of photocycloadducts 11 and 27, the analogous reaction of cyclohexene photocycloadduct 12 was found to result in a ring expansion and gave a 3:2 mixture of two stereoisomeric 8-membered lactams 24[17] (14% yield). The isomeric cyclohexene adduct 13, on the other hand, resulted only in a complex mixture of products. The paths leading to product 23 (and also 29) are outlined in Scheme 1.

The results reported above demonstrate a substantial difference between oxa- and aza-cycloadducts in the products. Thus, the regiospecific combination of the carbon-centered radical with the lactam oxygen takes place in the aza-series, while the corresponding carbon-centered radical 19 from the oxa-analogue combines regiospecifically with the ketonic oxygen although both 28 and 30 are formed in the case of oxa-adduct 26.

The factor which decides the direction of the combination of the carbon-centered radical is not clear but the observed difference in the regioselectivity may partly be attributed to an electronic factor that the amide oxygen is more electron rich than the ester oxygen due to the greater +M effect.[18]

References

1) Photoinduced Transformations. Part 78. Part 77. H. Suginome and S. Yamada, J. Org. Chem., in press.
2) For a riview of the 2+2 photocycloaddition of an α,β-unsaturated carbonyl compound with an alkene, see S. W. Baldwin, "Organic Photochemistry", ed by A. Padwa, M. Dekker Inc., New York, N.Y. (1981), Vol. 5, Chap.2, pp. 123-225.
3) H. Suginome, C. F. Liu, and A. Furusaki, Chem. Lett., **1984**, 911.
4) H. Suginome, C. F. Liu, and A. Furusaki, Chem. Lett., **1985**, 27.
5) a) R. G. Hunt, C. J. Potter, S. T. Reid, and M. L. Roantree, Tetrahedron Lett., **1975**, 2327. b) C. Kaneko, T. Naito, and M. Ito, Chem. Pharm. Bull., **28**, 3150 (1980) and subsequent papers.
6) Mp 238-240 °C. ^{1}H NMR (200 MHz, CDCl$_3$) δ 1.98 (s, 3H, OAc), 2.91 (d, 1H, *J*= 6.83 Hz, C*H* adjacent to C=O) and 8.37 (bs, 1H, NH); IR (Nujol), 1684 (lactam C=O) and 1740 cm^{-1} (OAc); MS *m/e* 271 (M$^+$, 2.0%) and 161 (100).
7) Mp 225-227 °C. ^{1}H NMR (90 MHz, CDCl$_3$) δ 2.18 (s, 3H, OAc), 3.69 (d, 1H, *J*= 8.79 Hz, CH adjacent to C=O) and 9.17 (bs, 1H, NH); IR (Nujol), 1666 (lactam C=O) and 1750 cm^{-1} (OAc); MS *m/e* 285 (M$^+$, 0.2%) and 161 (100).
8) Mp 255-258 °C. ^{1}H NMR (90 MHz, CACl$_3$) δ 1.95 (s, 3H, OAc), 3.37 (d, 1H, J= 10.33 Hz, CH adjacent to C=O) and 8.27 (bs, 1H, NS); MS *m/e* 285 (M$^+$, 2.4%) and 161 (100).
9) The intensity measurements were performed at the High Brilliance X-Ray Laboratory of Hokkaido University.
10) A. Furusaki, Acta Crystallogr., Sect. A, **35**, 220 (1979).
11a) Mp 180-182 °C. 11b) Mp 169-171 °C. 11c) Mp 189-191 °C. 11d) Mp 132 °C. 11e) Mp 173-175 °C. 11f) Mp 168.5-171.5 °C.
12) An inseparable 56:44 mixture of 12 and 13. Mp 163-173 °C.
13) Mp 192-194 °C. ^{1}H NMR (90 MHz, CDCl$_3$) δ 0.84, 0.88, 1.18,and 1.36 (each s, each 3H, 4C-Me), 1.92 (s, 3H, OAc), 3.26 (s, 1H, CH adjacent to C=O) and 8.86 (bs, 1H, NH); IR (Nujol) 1673 (lactam C=O) and 1773 cm^{-1} (OAc); MS *m/e* 287 (M$^+$, 3.4%) and 162 (100).
14) Mp 187-188 °C.
15) Mp 175-177.5 °C. ^{1}H NMR (90 MHz, CDCl$_3$) δ 3.66 (s, 3H, NMe) and 5.37-5.49 (m, 1H, -CHO-); IR (Nujol) 1589 and 1615 cm^{-1} (CO-C=C); MS *m/e* 241 (M$^+$, 100%).
16) Mp 217-218 °C. ^{1}H NMR (90 MHz, CDCl$_3$) δ 1.43 (s, 12H, 4Me) and 3.65 (s, 3H, NMe); IR (Nujol) 1585 and 1617 cm^{-1} (CO-C=C); MS *m/e* 257 (M$^+$, 13.7%) and 242 (M$^+$-Me, 100).
17) Mp 162-165 °C. ^{1}H NMR (90 MHz, CDCl$_3$) δ 3.17 (s, NMe of major lactam) 3.27 (s, NMe) 5.32 (d, J=8.79, -CH-I of major lactam) and 4.82 (d, J=10.33, CHI); IR (Nujol) 1650 (lactam C=O) and 1700 cm^{-1} (C$_6$H$_5$C=O); MS *m/e* 383 (M$^+$, 89.3%) 256 (M$^+$-I, 93.3) and 134 (100).
18) All the new compounds described in this paper gave satisfactory analytical results and spectroscopic (^{1}H NMR, IR, Mass.) data.

(Received March 6, 1985)