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PHOTOCHEMICAL REACTIONS OF 4-METHOXY-1-THIOCOUMARIN AND SYNTHESIS OF 1,2-DIHYDROCYCLOBUTA[c][1]BENZOTHIOPYRAN-3(3H)-ONES[1)]

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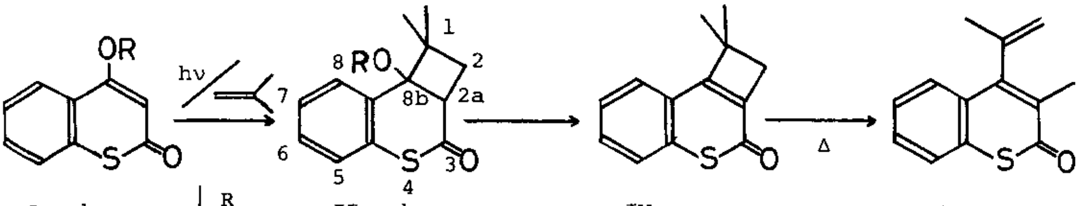
Abstract — 4-Methoxy-1-thiocoumarin reacts photochemically with monosubstituted olefins to give the head-to-tail adducts: 1-substituted 8b-methoxy-1,2,2a,8b-tetrahydrocyclobuta[c][1]benzothiopyran-3(3H)-ones, which eliminate methanol under appropriate conditions to give 1-substituted 1,2-dihydrocyclobuta[c][1]benzothiopyran-3(3H)-ones. Interesting photochemical ring-contraction reactions of 4-methoxy-1-thiocoumarin to benzo[b]thiophene derivatives are also reported.

We have already shown that intermolecular 2+2 cycloaddition of heteroaromatic enone compounds having an alkoxy function at the β-position, namely, 4-methoxy-2-pyridone,[2)] 2-quinolone,[3)] and 1-coumarin,[4)] to olefins can be effected photochemically and the related adducts can be transformed to the heteroaromatics with a cyclobutane ring fused at the [c]-position in their ring systems.

In an extension for the study of cyclobutane-fused heteroaromatics,[5)] we applied this two-step procedure to 4-methoxy-1-thiocoumarin (Ia). So far, except for photochemical dimerization of some 1-thiocoumarin derivatives,[6)] none of the photochemical behaviour of 1-thiocoumarin derivatives had been reported. As a result, we have not only succeeded in the synthesis of 1,2-dihydrocyclobuta[c][1]-benzothiopyran-3(3H)-ones, but also found interesting photochemical ring-contraction reactions of 4-methoxy-1-thiocoumarin to benzo[b]thiophene derivatives.

A solution of 4-methoxy-1-thiocoumarin[7)] (Ia) in acetonitrile in the presence of an excess of isobutene was irradiated at ≥300 nm (Toshiba 400P high-pressure mercury lamp, Pyrex filter) until disappearance of the starting material.[8)] Evaporation of the solvent followed by silica gel column chromatography gave the adduct (IIa, oil, 30%) and 3-methoxybenzo[b]thiophene (III, oil, 29%).[9)] The structure of the adduct (IIa) was provided from PMR spectrum [δ($CDCl_3$): 0.76 s (3H), 1.31 s (3H), 1.66 dd (H_2), 2.14 dd ($H_{2'}$), and 3.41 dd (H_{2a}) with $J_{H_2-H_{2'}}$ = 11 Hz, $J_{H_2-H_{2a}}$ = 9.5 Hz, and $J_{H_{2'}-H_{2a}}$ = 10 Hz], in which the appearance of 2a-proton signal as a doublet of doublets centered at δ 3.41 indicated the head-to-tail structure. The structure of III was assigned as 3-methoxybenzo[b]thiophene by the comparison of its spectral data [δ($CDCl_3$): 3.90 s (3H), 6.15 s (1H), 7.0–7.35 m (2H), and 7.4–7.8 m (2H), and UV, λ_{max}^{MeOH} nm: 240, 294, and 303] and the melting point of the picrate (mp 117–118°C) with those reported.[10)]

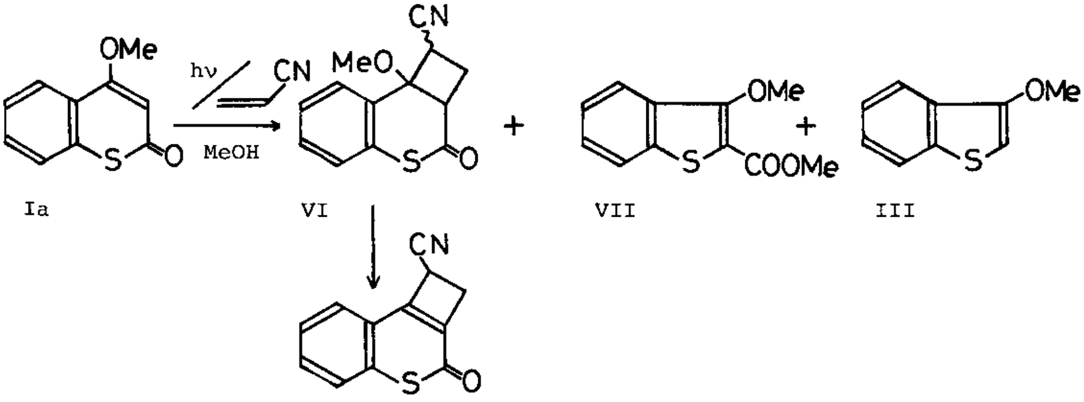
Treatment of the adduct (IIa) with boron trifluoride etherate in benzene at room temperature led to the selective formation (88%) of 1,1-dimethyl-1,2-dihydrocyclo-



Ia, b IIa, b IV V

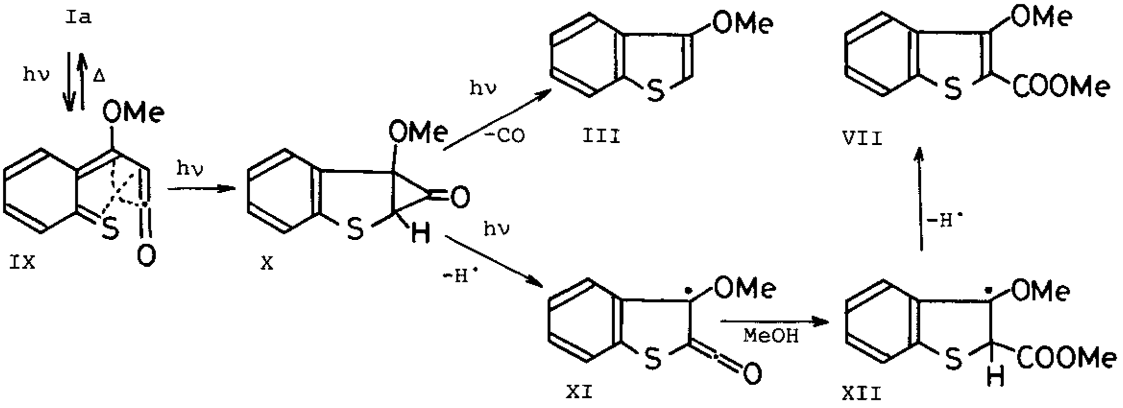
	R
a	Me
b	COMe

buta[*c*][1]benzothiopyran-3(3H)-one [IV, mp 100-101°C, δ($CDCl_3$): 1.55 s (6H), 2.82 s (2H), 7.15-7.55 m (4H), UV λ_{max}^{MeOH} nm (log ε): 212 (4.41), 230 (4.42), 264 (3.74), 305 (3.96), and 340 (3.63), IR ν(KBr) cm^{-1}: 1637]. The same compound (IV) was also formed under these conditions from the adduct (IIb, mp 116-118°C, 62%), which was obtained in 45% yield by photochemical cycloaddition of 4-acetoxy-1-thiocoumarin⁶⁾ (Ib) to isobutene in methanol. By heating in *o*-dichlorobenzene, IV rearranged to 4-isopropenyl-3-methyl-1-thiocoumarin [V, mp 104-105°C, δ($CDCl_3$): 2.03 bd (J=1.2 Hz, 3H), 4.87 bs and 5.38 m (each 1H, $J_{geminal}$= 1.7 Hz), 2.13 s (3H), 7.0-7.45 m (3H), and 7.45-7.8 m (1H), ν(KBr) cm^{-1}: 1605] in quantitative yield. Such rearrangement has ample precedents in 1,1-dimethylbenzocyclobutenes11) and their hetero-analogues.5) Essentially in the same manner, 1-cyano-1,2-dihydrocyclobuta[*c*][1]benzothiopyran-3(3H)-one [VIII, mp 182-183°C, λ_{max}^{MeOH} nm (log ε): 211 (4.43), 222 (4.39), 237 (4.37), 265 (3.69), 304 (3.93), and 343 (3.59), ν(KBr) cm^{-1}: 2230 and 1655] was synthesized from Ia in the above two-step procedure. In this case, the adduct (VI, oil) was obtained in 61% yield by irradiation of Ia in methanol in the presence of 100 mol equivalent of acrylonitrile. PMR spectrum of VI showed its methoxy signals at δ 3.05 and 2.94 in the intensity ratio of *ca*. 2:1, showing it as a diastereoisomeric mixture due to the 1-cyano group. Methyl 3-methoxybenzo[*b*]thiophene-2-carboxylate (VII, mp 65-66°C, 7%) and a trace of III were obtained as detectable by-products. The structure of VII was determined by the comparison of melting point and spectral data with those of the literature.12) Though the adduct (VI) did not eliminate methanol by the above acidic condi-



Ia VI VII III

VIII



tions,4,13) the desired product (VIII) was obtained in 62% yield by treatment (reflux, 1 min) with potassium *t*-butoxide in benzene.14)

In order to clarify the mechanism for the formation of benzo[*b*]thiophene derivatives (III and VII), Ia was irradiated in methanol under argon. As a result, VII was obtained in 25% yield and a lot of tarry material and a trace of III were also formed. It seems noteworthy that much longer irradiation time is necessary for the consumption of Ia in methanol than in the co-existence of olefins. Taking into account these facts and feasible electrocyclic photochemical ring openings of the related heteroaromatic compounds15) (*e.g.*, 2-pyrones, 2-pyridones, and their higher benzenoid homologues), the formation of these benzo[*b*]thiophenes seems to be explained by assuming a photochemical ring opening of the 1-thiocoumarin to give an intermediate (IX) which would revert to the starting material thermally with partial decomposition. The intermediate (IX) would partly undergo under these conditions a subsequent intramolecular [4+2] photoaddition to give the tricyclic compound (X).16) Some possible routes to III and VII are shown in the Chart.

Though the mechanism for the formation of benzo[*b*]thiophenes shown above is tentative at present, such ring contraction reactions can be prevented by the use of a large excess of olefins. The present study thus provides a further successful example for the application of our two-step synthesis of cyclobutane-fused heteroaromatics to 1-thiocoumarin series.

REFERENCES AND NOTES

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2) H. Fujii, K. Shiba, and C. Kaneko, *J. Chem. Soc. Chem. Comm.*, **1980**, 537.

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5) Synthesis and reactions of cyclobutane-fused heteroaromatics have been reviewed: C. Kaneko and T. Naito, *Heterocycles*, 1982, **19**, 2183.

6) J. Lehmann and H. Wamhoff, *Liebigs Ann. Chem.*, **1974**, 1287.

7) Methylation of 4-hydroxy-1-thiocoumarin by diazomethane in ether afforded Ia (mp 124-125.5°C) and 2-methoxythiochromone (mp 133-135.5°C) in the respective yields of 56 and 32%.

8) Irradiation was carried out using 3-5 mM solution of 4-methoxy- (Ia) and 4-acetoxy-1-thiocoumarin (Ib). Under these conditions, no photodimer6) was obtained even by irradiation in the absence of olefins.

9) The structures of the products were supported by acceptable combustion data and/or mass spectra, and other satisfactory spectral data.

10) A.S. Angeloni and M. Tramontini, *Ann. Chim. (Rome)*, 1963, **53**, 1740.

11) T. Kametani, M. Tsubuki, Y. Shiratori, Y. Kato, H. Nemoto, M. Ihara, K. Fukumoto, F. Sato, and H. Inoue, *J. Org. Chem*., 1977, **42**, 2672.

12) Y. Matsuki and Y. Adachi, *Nippon Kagaku Zasshi*, 1968, **89**, 192.

13) Lewis-acid catalyzed elimination of methanol from the adduct of the type (VI) having an electron-withdrawing group at the 1-position generally failed to give the cyclobutene even for quinolone and coumarin series. A possible reason for this phenomena has been discussed in reference 4.

14) Since these compounds (III and VIII) suffer a ready solvolytic ring opening under basic conditions in protic solvents, the condition (NaOMe or KOH in methanol) applicable generally for the synthesis of cyclobutane-fused azaheteroaromatics5) can not be used for these compounds. The present method was also successfully applied to the synthesis of related 1,2-dihydrocyclobuta[*c*]coumarins from the corresponding adducts.

15) See for examples: a) C. Kaneko, T. Naito, and C. Miwa, *Heterocycles*, 1982, **19**, 2275; b) C. Kaneko, H. Fujii, and K. Kato, *Heterocycles*, 1982, **17**, 395.

16) This transformation (IX ⟶ X) would be closely analogous to the photo-Diels-Alder reaction encountered with 1,3,5-hexatrienes and related heteroanalogues: A. Padwa, A. Au, G.A. Lee, and W. Owens, *J. Org. Chem*., 1975, **40**, 1142 and references cited therein.

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