Novel cycloaddition of 2-alkyl-3-benzoyl-2-thianaphthalenes

Hiroshi Shimizu,*[a] Takenori Yonezawa,[a] Tomoko Watanabe[a] and Kazuhiro Kobayashi[b]

[a] *Institute of Manufacturing Pharmacy, Gifu Pharmaceutical University, 6-1, Mitahora-higashi 5-chome, Gifu 502, Japan*
[b] *Taiho Pharmaceutical Co. Ltd., Hanno Research Center, 1-27, Misugidai, Hanno, Saitama 357, Japan*

Deprotonation of 2-alkyl-3-benzoyl-2-thiochromenium salts 1 or 2 with 2 equiv. of triethylamine in ethanol affords the unexpected benzothiopyran derivatives 3 and 4; the structure of 3a is confirmed by X-ray crystallography.

The stability of 2-thianaphthalenes with a conjugated cyclic sulfur ylide structure has been reported to be dependent upon the substituent at the 1-position: 1-unsubstituted or 1-alkyl group substituted 2-alkyl-2-thianaphthalenes are unstable and undergo 1,2-rearrangement of the substituent from sulfur to carbon resulting in the corresponding 1-substituted 2-thiochromenes in relatively good yields.[1] In contrast, 2-thianaphthalenes bearing an electron-withdrawing group (EWG) such as a cyano or benzoyl group at the 1-position are resonance stable and are isolated as yellow or orange crystals.[2]

In our continuing studies on the chemistry of 2-thianaphthalenes, we were interested in the stability and reactivity of 2-thianaphthalenes bearing an electron-withdrawing group at the 3-position, because if the ylide carbanion at the 1-position delocalizes to the 3-position by resonance, the 2-thianaphthalene will have an *o*-quinodimethane structure resulting in interesting reactivity.

We carried out deprotonation of 3-benzoyl-2-methyl-2-thiochromenium tetrafluoroborate **1a** with 2 equiv. of triethylamine in ethanol in the hope to prepare the corresponding 2-thianaphthalene and, interestingly, we obtained the unexpected 2-benzothiopyran derivative **3a**† and ethyl benzoate **5a** in 52 and 38% yields, respectively. Deprotonation of **1a** with strong base such as NaH, LDA and DBU did not afford the product **3a**, but only inseparable complex mixtures. The structure of **3a** was elucidated on the basis of spectral results which showed an IR absorption at 1660 cm^{-1} (CO); ^1H NMR signals at δ 3.68 and 3.83 with coupling constants (*J*) of 7.8 Hz were each attributable to the two methine protons of the cyclopropane ring. The signals at δ 4.61 and 4.68 with *J* = 3.9 Hz were each due to the two methine protons of the tetrahydrothiophene ring and the signals at δ 3.44 and 3.53 with *J* = 13.2 Hz were due to the methylene protons. The mass spectral peak at *m/z* 414 (M^+) shows the molecular formula to be $C_{26}H_{22}OS_2$. The final confirmation of the structure of **3a** was obtained by an X-ray crystal structure determination‡ and is illustrated in Fig. 1. The X-ray structure of compound **3a** shows that the S-methyl group is located just above the benzene ring of the benzoyl group and causes an upfield shift (δ 1.69) of the S-methyl signal in the ^1H NMR spectrum compared to an ordinary S-methyl group. The relevant bond distances between the methyl hydrogens and the Csp^2 carbons of the benzene ring are 2.92, 2.95, 2.96, 3.04 and 3.05 Å for H(21)–C(24), H(21)–C(14), H(22)–C(17), H(21)–C(15) and H(22)–C(18), respectively. These values are very close to the sum of the van der Waals radii of H and C, suggesting the presence of some attractive force such as CH–π interaction[3] between the benzene ring and the methyl hydrogens. Similarly, treatment of 2-ethyl-2-thiochromenium salt **2a** with triethylamine afforded the corresponding 2-benzothiopyran **4a** and ethyl benzoate **5a** in 65 and 74% yields, respectively.

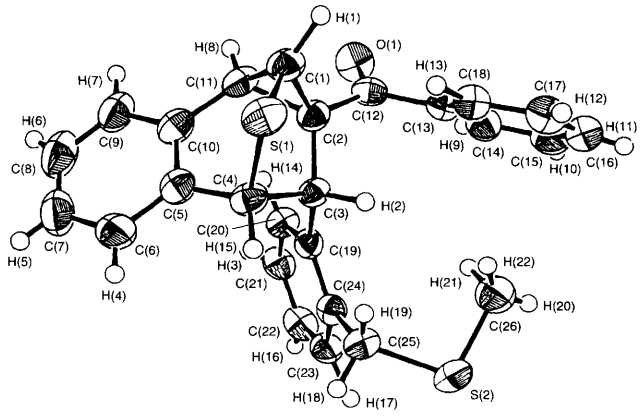
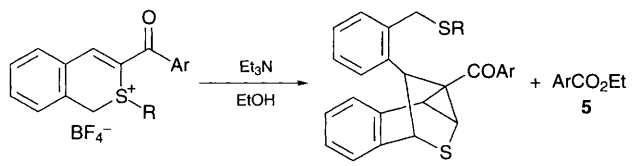


Fig. 1 Molecular structure of **3a**. Selected bond distances (Å) and angles (°): H(21)–C(14) 2.95(5), H(21)–C(15) 3.04(5), H(21)–C(24) 2.92(5), H(22)–C(17) 2.96(5), H(22)–C(18) 3.05(5), C(26)–C(15) 3.64(1), C(26)–C(16) 3.53(1), C(26)–C(17) 3.615(9), S(1)–C(1) 1.774(6), S(1)–C(4) 1.849(6), C(1)–C(2) 1.533(7), C(1)–C(11) 1.538(8), C(2)–C(11) 1.537(7), C(2)–C(3) 1.529(7), C(3)–C(4) 1.571(7); C(1)–S(1)–C(4) 89.5(3), S(1)–C(1)–C(2) 110.7(4), C(1)–C(2)–C(11) 60.1(4), C(1)–C(11)–C(2) 59.8(3), C(2)–C(1)–C(11) 60.1(4), C(25)–S(2)–C(26) 99.5(3), S(2)–C(25)–C(24) 112.7(4).

Table 1 Deprotonation of 2-thiochromenium salts **1** and **2** with triethylamine in ethanol[a]

Entry	2-Thiochromenium salt	*t*/h	Yield (%) 3	4	5
1	**1a**	12	52		38
2	**2a**	12		65	74
3	**2a**	48		72	60
4	**1b**	12	66		59
5	**2b**	12		75	63
6	**1c**	12	85		83
7	**2c**	12		86	79
8	**1d**	12	38		55
9	**2d**	12		65	74

[a] Reactions were performed at 60 °C.



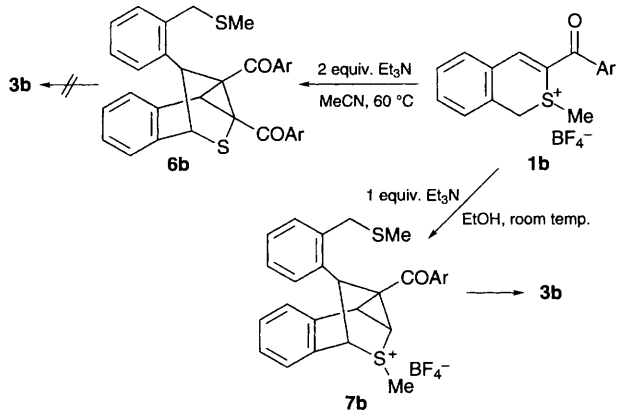
1 R = Me, **2** R = Et
a Ar = Ph
b Ar = *p*-ClC_6H_4
c Ar = *p*-BrC_6H_4
d Ar = *p*-PhC_6H_4

3 R = Me
4 R = Et

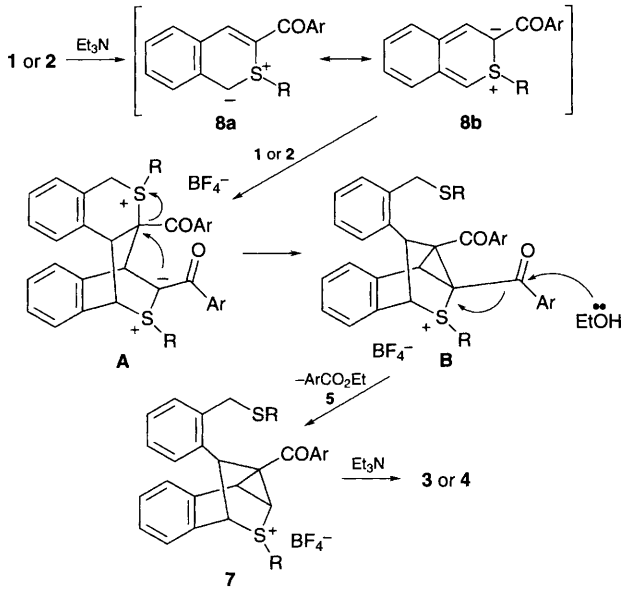
Scheme 1

In order to investigate the generality of the above unexpected reaction of 3-benzoyl-2-thianaphthalenes, we studied the reactions of other 3-aroyl-2-thiochromenium salts **1b–d**, **2b–d** with triethylamine in ethanol. The results are summarized in Table 1. In all cases, similar reactions proceeded to give the 2-benzothiopyran derivatives **3b–d**, **4b–d**, respectively. 4-Bromobenzoyl substituted thiochromenium salts **1c** and **2c** (entries 6 and 7) resulted in high yields of the products.

In order to put forward a plausible mechanism for the formation of the products **3** or **4** and **5**, we carried out the following reactions using the 2-thiochromenium salt **1b** (Scheme 2). (i) The above reaction was performed in acetonitrile instead of ethanol and gave the dibenzoyl compound **6b** in 74% yield. (ii) **6b** was treated with an excess of triethylamine in ethanol which resulted in the recovery of **6b**, indicating that **6b** is not an intermediate for the above reaction. (iii) Triethylamine (1 equiv.) was used for the above reaction under mild conditions (room temperature) to afford the sulfonium compound **7b** in 21% yield. (iv) Treatment of the sulfonium compound **7b** with triethylamine in ethanol caused demethylation to afford the benzothiopyran **3b** in 70% yield.



Scheme 2



Scheme 3

On the basis of the above experimental evidence, we propose a mechanism for the formation of products **3** or **4** and **5** as depicted in Scheme 3. Deprotonation of the 2-thiochromenium salt **1** or **2** with triethylamine generates the corresponding ylidic 2-thianaphthalene **8a** which resonates with the *o*-quinodimethane structure **8b**. The probable cycloaddition of the 2-thianaphthalene **8** with a remaining 2-thiochromenium salt **1** or **2** gives the sulfonium ylide intermediate **A**. Intramolecular attack of the ylidic carbanion of the intermediate **A** on the carbon atom attached to an another sulfonino group constructs a cyclopropane ring and affords the intermediate **B**. The carbonyl carbon activated with sulfonino moiety of the intermediate **B** next undergoes nucleophilic attack with ethanol (the reaction solvent) to release ethyl benzoate **5** and gives the sulfonium compound **7**, which undergoes dealkylation by nucleophilic attack of triethylamine to furnish the final product **3** or **4**.

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Footnotes

† Satisfactory analytical and spectral data were obtained for all new compounds.

‡ *Crystal data* for **3a**: $C_{26}H_{22}OS_2$, triclinic, a = 9.765(3), b = 12.845(4), c = 8.834(4) Å, α = 97.27(3), β = 107.17(3), γ = 96.53(3)°, space group $P\bar{1}$ (#2), V = 1036.8(7) Å^3, Z = 2, D_c = 1.328 g cm^{-3}, crystal dimensions 0.30 × 0.25 × 0.30 mm, μ(Mo-Kα) = 2.60 cm^{-1}; diffractometer: Rigaku AFC5R, radiation: Mo-Kα (λ = 0.71069 Å), scan range: 41.96° < 2θ < 47.56°, scan type: ω-2θ, standard reflection: 3 standards/150 reflections, independent reflections: 3129, R_{int} = 0.053; R = 0.056, R_w = 0.071, GOF = 7.39. Atomic coordinates, bond lengths and angles, and thermal parameters have been deposited at the Cambridge Crystallographic Data Centre (CCDC). See Information for Authors, Issue No. 1. Any request to the CCDC for this material should quote the full literature citation and the reference number 182/103.

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