The Synthesis of Naphthothiopyranopyranones and Naphthothiopyranopyranthiones

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The synthesis of fused tetracyclic naphthothiopyranopyranones from dihydronaphthothiopyranones **I** or **II** has been studied. Compounds **I** or **II** have been cyclised in good yield to the corresponding dioxaborin difluoride complexes **III, IV, XIII** and **XIV** by treatment with acetic or propionic anhydride and boron trifluoride etherate. These complexes and the Vilsmeier reagent reacted to produce fused tetracyclic 3-substituted naphthothiopyranopyranones **V, VI, XV** or **XVI**.

The reaction of dioxaborin difluoride complexes **III** or **IV** with dimethylthioformamide (DMTF) afforded dimethylaminovinyldioxaborin difluoride complexes **IX** or **X**. Treatment of **IX** or **X** with hydrochloric acid solution gave naphthothiopyranopyranones **VII** or **VIII**.

The reaction of **VII, VIII, XV** or **XVI** with DMTF/acetic anhydride yielded new products, which was identified as naphthothiopyranopyranthions **XI, XII, XVII** or **XVIII**.

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Pyranochromone ring compounds and chromanochromanone ring compounds such as citromycetin and rotenoid widely distributed in nature [1] possess a biological activity [2,3].

There have been many reports [4] on the synthesis of above fused pyranopyranone ring compounds. However, only a few studies on the synthesis of its thiopyrano ring derivatives have been documented in the literature.

Phillipp *et al.* [5a-b] has shown that the synthesis of [1]-benzo-thiopyrano[4,3-*b*]pyran-4-one can be accomplished *via* the dioxaborin difluoride complex intermediate which was obtained by the acylation of thiochroman-4-one in the presence of boron trifluoride etherate. Furthermore, Nakib *et al.* [6] has shown that the reaction of 3-benzylidenethiochroman-4-one with malononitrile affords 2-amino-4-aryl-3-cyano[1]benzothiopyrano[4,3-*b*]pyran.

In the previous paper [7], we reported the synthesis of 3-substituted benzochromones prepared by the Vilsmeier reaction of the dioxaborin difluoride complexes which were obtained by the acylation of naphthol with excess acetic acid and its derivatives in the presence of boron trifluoride etherate.

On the basis of previous experience, we now wish to report the synthesis of fused tetracyclic 3-substituted pyranone derivatives, naphthothiopyranopyranones and naphthothiopyranopyranthiones, starting from 2,3-dihydro-4*H*-naphtho[1,2-*b*]thiopyran-4-one (**I**) and 2,3-dihydro-1*H*-naphtho[2,1-*b*]thiopyran-1-one (**II**).

The dioxaborin difluoride complex, 2,2-difluoro-4-methyl-5*H*-naphtho[1′,2′:6,5]thiopyrano[3,4-*e*]-1,3,2-dioxaborin (**III**), was obtained from **I** with excess acetic anhydride and boron trifluoride etherate at 60° for 1 hour in 78% yield. Furthermore, 2,2-difluoro-4-methyl-5*H*-naphtho-[1′,2′:5,6]thiopyrano[3,4-*e*]-1,3,2-dioxaborin (**IV**) was prepared from **II** in 82% yield. In a similar manner, the reaction of **I** or **II** with propionic anhydride afforded corresponding dioxaborin difluoride complexes, 4-ethyl-2,2-difluoro-5*H*-naphtho[1′,2′:6,5]thiopyrano[3,4-*e*]-1,3,2-dioxaborin (**XIII**) or 4-ethyl-2,2-difluoro-5*H*-naphtho[1′,2′:5,6]-thiopyrano[3,4-*e*]-1,3,2-dioxaborin (**XIV**) in 73% and 75% yield, respectively. However, the above reaction using acetic acid, propionic acid instead of its anhydrides failed to occur.

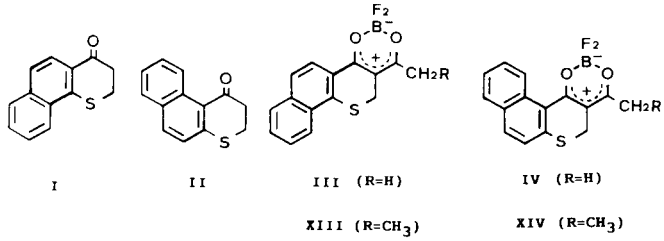
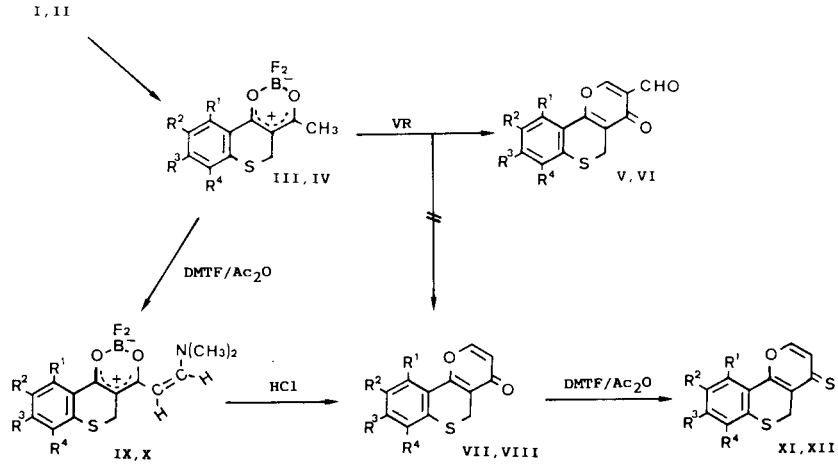


Figure 1

The reaction of **III** or **IV** with double the molar amount of Vilsmeier reagent which was accessible by DMF with phosphoryl chloride afforded quantitative yield of 3-formyl-4*H*,5*H*-naphtho[1′,2′:6,5]thiopyrano[4,3-*b*]pyran-4-one (**V**) or 3-formyl-4*H*,5*H*-naphtho[1′,2′:5,6]thiopyrano-[4,3-*b*]pyran-4-one (**VI**), respectively. The equimolar reaction of **IV** with the Vilsmeier reagent, however, did not produced expected naphthothiopyranopyranone compound, 4*H*,5*H*-naphtho[1′,2′:5,6]thiopyrano[4,3-*b*]pyran-4-one (**VIII**), and gave **VI** in 49%, then 50% of **IV** was recovered.

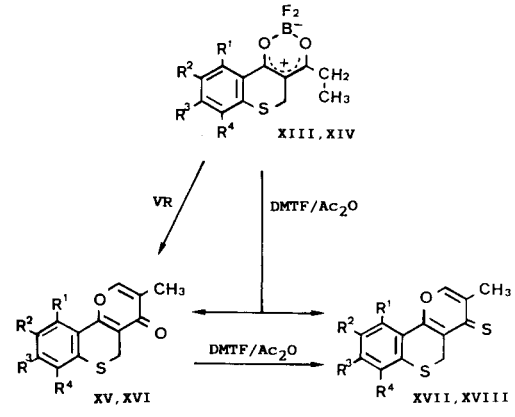
Since the direct synthesis of **VIII** by the Vilsmeier reaction of **IV** was unsuccessful, an alternative route to naphthothiopyranopyranones was investigated. The synthetic approach to naphthothiopyranopyranones was initiated incorporating a dimethylaminovinyl group in **III** and **IV**,



followed by treatment with hydrochloric acid. It has been found that the reactivity of amides for the formation of dimethylaminovinyldioxaborin difluoride complexes **IX** or **X** plays an important role; the reaction of DMF with **III** in acetic anhydride gave 2,2-difluoro-4-(2-dimethylaminovinyl)-5*H*-naphtho[1′,2′:6,5]thiopyrano[3,4-*e*]-1,3,2-dioxaborin (**IX**) in only 30% yield, while a similar reaction using dimethylthioformamide (DMTF) [8] instead of DMF gave **IX** in 73% yield. 2,2-Difluoro-4-(2-dimethylaminovinyl)-5*H*-naphtho[1′,2′:5,6]thiopyrano[3,4-*e*]-1,3,2-dioxaborin (**X**) was also prepared from **IV** with DMTF in 84% yield. The structures of **IX** and **X** were assigned by ^{1}H-nmr spectrum; compound **IX** showed two doublet signals (J = 11.72 Hz) at δ 5.51 ppm and δ 8.30 ppm attributable to the *cis*-configurational vinyl protons and two singlet signals at δ 2.15 ppm, δ 3.43 ppm for methyl protons belonging to the dimethylamino group, and compound **X** also exhibits similar signals. Compound **VII** together with **VIII** were prepared by the subsequent cyclization of **IX** and **X** in hydrochloric acid to give in 75% and 70% yield, respectively.

On the other hand, in the case of the equimolar Vilsmeier reaction of **XIII**, **XIV** produced methylnaphthothiopyranopyranones, 3-methyl-4*H*,5*H*-naphtho[1′,2′:6,5]-thiopyrano[4,3-*b*]pyran-4-one (**XV**) and 3-methyl-4*H*,5*H*-naphtho[1′,2′:5,6]thiopyrano[4,3-*b*]pyran-4-one (**XVI**) in 82% and 94% yield. The reaction of **XIII** with DMTF in acetic anhydride did not produce any dimethylaminovinyldioxaborin difluroide complexes such as **IX**, but afforded a mixture of **XV** in 30% yield with 24% yield of its thione analog, 3-methyl-4*H*,5*H*-naphtho[1′,2′:6,5]thiopyrano-[4,3-*b*]pyran-4-thione (**XVII**) with no C=O absorption and the appearance of C=S (1127 cm^{-1}) absorption in the ir spectrum. A similar reaction of **XIV** gave 3-methyl-4*H*,5*H*-naphtho[1′,2′:5,6]thiopyrano[4,3-*b*]pyran-4-thione (**XVIII**) in 31% yield with no thiopyranopyranone **XVI**.

The formation of pyranthiones **XVII** and **XVIII** can be interpreted as the sulfurization of the carbonyl group of pyranones **XV** and **XVI** with DMTF. In fact, the compounds **XV** and **XVI** on treatment with an acetic anhydride solution of DMTF afforded **XVII** and **XVIII** in about 50% yield and a similar reaction of **VII** and **VIII** gave pyranthiones, 4*H*,5*H*-naphtho[1′,2′:6,5]thiopyrano-[4,3-*b*]pyran-4-thione (**XI**) and 4*H*,5*H*-naphtho[1′,2′:5,6]-thiopyrano[4,3-*b*]pyran-4-thione (**XII**), in 83% and 68% yield, respectively.



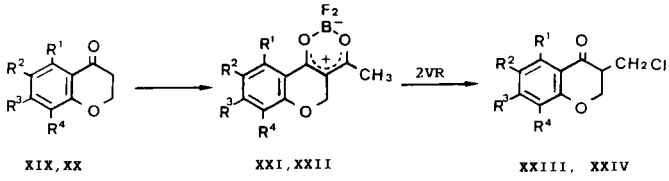
There is no report that such a substitution of conjugated ketones with DMTF would afford the corresponding thioketones. We have now under investigation the application of this reaction.

We have also tried the reaction of 2,3-dihydro-4*H*-naphtho[1,2-*b*]pyran-4-one (**XIX**) and 2,3-dihydro-1*H*-naphtho-

[2,1-*b*]pyran-1-one (**XX**) which is compared with the reaction of **I** and **II**.

Treatment of **XIX** and **XX** with acetic anhydride and boron trifluoride etherate gave the corresponding dioxaborin difluoride complexes **XXI** and **XXII**. The reaction of **XXI** and **XXII** with double the molar amount of the Vilsmeier reagent unexpectedly furnished products of mp 172°, **XXIII**, and mp 139°, **XXIV** and a small yield of the corresponding formylnaphthopyranopyranones.

Compound **XXIII** revealed a C=O band in the ir spectrum and a doublet signal at δ 4.62 ppm for a methylene group adjacent to the chlorine atom and the absence of the signal for a methyl group in the ^{1}H-nmr spectrum and the parent ion peak at m/z 244 in the mass spectrum which indicated a molecular formula of $C_{14}H_9O_2Cl$. On the basis of the above observation the product was identified as 3-chloromethyl-4*H*-naphtho[1,2-*b*]pyran-4-one and compound **XXIV** identified in a similar investigation as 2-chloromethyl-1*H*-naphtho[2,1-*b*]pyran-1-one. It is considered that the formation of **XXIII** and **XXIV** which was explained by the subsequent reaction of **XIX** and **XX** with the Vilsmeier reagent yielded *in situ* deacetylation of dioxaborin difluoride complexes **XXI** and **XXII**.



XIX, XX XXI, XXII XXIII, XXIV

EXPERIMENTAL

Melting points were determined by using of Yanagimoto melting point apparatus and uncorrected. The ^{1}H-nmr were obtained with a JEOL JNM-GX400 spectrometer in the indicated solvents. Chemical shifts and coupling constants were measured in ppm (δ) and J (Hz) with respect to TMS. The mass spectra were obtained on a Hitachi M-80B spectrometer. Elemental analyses were performed on a Perkin-Elmer 240C elemental analyzer.

2,3-Dihydro-4*H*-naphtho[1,2-*b*]thiopyran-4-one (**I**) [9], 2,3-Dihydro-1*H*-naphtho[2,1-*b*]thiopyran-1-one (**II**) [10], 2,3-Dihydro-4*H*-naphtho[1,2-*b*]pyran-4-one (**XIX**) [11] and 2,3-Dihydro-1*H*-naphtho[2,1-*b*]pyran-1-one (**XX**) [10] were made by literature methods.

General Synthesis of the Dioxaborin Difluoride Complexes.

Boron trifluoride etherate (20 mmoles) was added dropwise to a mixture of dihydronaphthothiopyranones **I** or **II** (15 mmoles) with acetic or propionic anhydride (50 mmoles) under a nitrogen atmosphere and the mixture was stirred at 60° for 1 hour. After cooling, the cyrstalline solid separated was filtered, washed with water and recrystallized from toluene to give dioxaborin difluoride complexes, **III**, **IV**, **XIII** and **XIV**. When the reactions were carried out using dihydronaphthopyranones **XIX** and **XX** with acetic anhydride and boron trifluoride etherate, dioxaborin difluoride complexes **XXI** and **XXII** were obtained.

2,2-Difluoro-4-methyl-5*H*-naphtho[1',2':6,5]thiopyrano[3,4-*e*]-1,3,2-dioxaborin (**III**).

This compound was obtained as yellow crystals, mp 268-270° (78% yield); ms: m/z [M$^+$] Found: 303.0562; Calcd. for $C_{15}H_{11}F_2O_2BS$: 303.0576; ^{1}H-nmr (deuteriochloroform): δ 2.53 (s, 3H, CH_3), 3.94 (s, 2H, S-CH_2), 7.62 (ddd, 1H, J = 8.24, 6.86, 1.37 Hz, C_8-H), 7.70 (ddd, 1H, J = 8.24, 6.86, 1.10 Hz, C_9-H), 7.71 (d, 1H, J = 8.79 Hz, C_{11}-H), 7.87 (dd, 1H, J = 8.24, 1.37 Hz, C_{10}-H), 8.16 (d, 1H, J = 8.79 Hz, C_{12}-H), 8.26 (dd, 1H, J = 8.24, 1.10 Hz, C_7-H).

Anal. Calcd. for $C_{15}H_{11}F_2O_2BS$: C, 59.40; H, 3.63; S, 10.56. Found: C, 59.36; H, 3.66; S, 10.55.

2,2-Difluoro-4-methyl-5*H*-naphtho[1',2':5,6]thiopyrano[3,4-*e*]-1,3,2-dioxaborin (**IV**).

This compound was obtained as yellow crystals, mp 218-220° (82% yield); ms: m/z [M$^+$] Found: 303.0566; Calcd. for $C_{15}H_{11}F_2O_2BS$: 303.0576; ^{1}H-nmr (deuteriochloroform): δ 2.55 (s, 3H, CH_3), 3.75 (s, 2H, S-CH_2), 7.41 (d, 1H, J = 8.67 Hz, C_7-H), 7.53 (ddd, 1H, J = 8.30, 7.08, 1.22 Hz, C_{10}-H), 7.66 (ddd, 1H, J = 8.30, 7.08, 1.22 Hz, C_{11}-H), 7.81 (dd, 1H, J = 8.30, 1.22 Hz, C_9-H), 7.89 (d, 1H, J = 8.67 Hz, C_8-H), 8.73 (dd, 1H, J = 8.30, 1.22 Hz, C_{12}-H).

Anal. Calcd. for $C_{15}H_{11}F_2O_2BS$: C, 59.40; H, 3.63; S, 10.56. Found: C, 59.43; H, 3.57; S, 10.51.

4-Ethyl-2,2-difluoro-5*H*-naphtho[1',2':6,5]thiopyrano[3,4-*e*]-1,3,2-dioxaborin (**XIII**).

This compound was obtained as orange crystals, mp 217-219° (73% yield); ms: m/z [M$^+$] Found: 317.0718; Calcd. for $C_{16}H_{13}F_2O_2BS$: 317.0729; ^{1}H-nmr (deuteriochloroform): δ 1.37 (t, 3H, J = 7.42 Hz, CH_2CH_3), 2.82 (q, 2H, J = 7.42 Hz, CH_2CH_3), 3.85 (s, 2H, S-CH_2), 7.62 (ddd, 1H, J = 8.24, 6.87, 1.37 Hz, C_8-H), 7.69 (ddd, 1H, J = 8.24, 6.87, 1.37 Hz, C_9-H), 7.71 (d, 1H, J = 8.24 Hz, C_{11}-H), 7.86 (dd, 1H, J = 8.24, 1.37 Hz, C_{10}-H), 8.15 (d, 1H, J = 8.24 Hz, C_{12}-H), 8.25 (dd, 1H, J = 8.24, 1.37 Hz, C_7-H).

Anal. Calcd. for $C_{16}H_{13}F_2O_2BS$: C, 60.57; H, 4.10; S, 10.09. Found: C, 60.55; H, 4.13; S, 10.08.

4-Ethyl-2,2-difluoro-5*H*-naphtho[1',2':5,6]thiopyrano[3,4-*e*]-1,3,2-dioxaborin (**XIV**).

This compound was obtained as a yellow powder, mp 170-172° (75% yield); ms: m/z [M$^+$] Found: 317.0718; Calcd. for $C_{16}H_{13}F_2O_2BS$: 317.0729; ^{1}H-nmr (deuteriochloroform): δ 1.38 (t, 3H, J = 7.57 Hz, CH_2CH_3), 2.84 (q, 2H, J = 7.57 Hz, CH_2CH_3), 3.74 (s, 2H, S-CH_2), 7.42 (d, 1H, J = 8.54 Hz, C_7-H), 7.53 (ddd, 1H, J = 8.06, 7.08, 1.22 Hz, C_{10}-H), 7.66 (ddd, 1H, J = 8.79, 7.08, 1.22 Hz, C_{11}-H), 7.81 (dd, 1H, J = 8.06, 1.22 Hz, C_9-H), 7.88 (d, 1H, J = 8.54 Hz, C_8-H), 8.74 (dd, 1H, J = 8.79, 1.22 Hz, C_{12}-H).

Anal. Calcd. for $C_{16}H_{13}F_2O_2BS$: C, 60.57; H, 4.10; S, 10.09. Found: C, 60.52; H, 4.15; S, 10.13.

2,2-Difluoro-4-methyl-5*H*-naphtho[1',2':6,5]pyrano[3,4-*e*]-1,3,2-dioxaborin (**XXI**).

This compound was obtained as a brown powder, mp 252-254° (67% yield); ms: m/z [M$^+$] Found: 287.0788; Calcd. for $C_{15}H_{11}F_2O_3B$: 287.0805; ^{1}H-nmr (DMSO-d_6): δ 2.46 (s, 3H, CH_3), 5.50 (s, 2H, O-CH_2), 7.66 (d, 1H, J = 9.07 Hz, C_{11}-H), 7.69 (dd, 1H, J = 8.24, 7.14 Hz, C_9-H), 7.78 (d, 1H, J = 9.07 Hz, C_{12}-H), 7.82 (dd, 1H, J = 8.51, 7.14 Hz, C_8-H), 8.02 (d, 1H, J = 8.24 Hz, C_{10}-H), 8.25 (d, 1H, J = 8.51 Hz, C_7-H).

Anal. Calcd. for $C_{15}H_{11}F_2O_3B$: C, 62.72; H, 3.83. Found: C, 62.70; H, 3.86.

2,2-Difluoro-4-methyl-5*H*-naphtho[1′,2′:5,6]pyrano[3,4-*e*]-1,3,2-dioxaborin (**XXII**).

This compound was obtained as yellow crystals mp 229-231° (76% yield); ms: m/z [M⁺] Found: 287.0790; Calcd. for $C_{15}H_{11}F_2O_3B$: 287.0805; ^{1}H-nmr (DMSO-d_6): δ 2.46 (s, 3H, CH_3), 5.27 (s, 2H, O-CH_2), 7.30 (d, 1H, J = 9.06 Hz, C_7-H), 7.58 (ddd, 1H, J = 7.97, 6.87, 1.10 Hz, C_{10}-H), 7.77 (ddd, 1H, J = 8.52, 6.87, 1.37 Hz, C_{11}-H), 8.02 (dd, 1H, J = 7.97, 1.37 Hz, C_9-H), 8.32 (d, 1H, J = 9.06 Hz, C_8-H), 8.72 (dd, 1H, J = 8.52, 1.10 Hz, C_{12}-H).

Anal. Calcd. for $C_{15}H_{11}F_2O_3B$: C, 62.72; H, 3.83. Found: C, 62.75; H, 3.82.

General Procedure for the Reaction of Dioxaborin Difluoride Complexes **III**, **IV**, **XIII**, **XIV**, **XXI** and **XXII** with the Vilsmeier Reagent.

The Vilsmeier reagent which was made up DMF (0.1 mole) with phosphoryl chloride (20 mmoles) was added to **III** or **IV** (10 mmoles) or **XIII** or **XIV** (20 mmoles), and the mixture was stirred at 100° for 2 hours. After cooling, the reaction mixture was poured into ice-water and then crystalline solid which separated was collected and recrystallized from cyclohexane to give 3-substituted naphthothiopyanopyranones **V**, **VI**, **XV** or **XVI**. In a similar manner, **XXI** or **XXII** (10 mmoles) reacted with the Vilsmeier reagent to produce **XXIII** and **XXIV**, respectively.

3-Formyl-4*H*,5*H*-naphtho[1′,2′:6,5]thiopyrano[4,3-*b*]pyran-4-one (**V**).

This compound was obtained as a yellow powder, mp 249-251° (99% yield); ms: m/z [M⁺] Found: 294.0360; Calcd. for $C_{17}H_{10}O_3S$: 294.0351; ^{1}H-nmr (deuteriochloroform): δ 4.12 (s, 2H, S-CH_2), 7.61-7.64 (m, 2H, C_8-H, C_9-H), 7.75 (d, 1H, J = 8.79 Hz, C_{11}-H), 7.86-7.88 (m, 1H, C_{10}-H), 7.88 (d, 1H, J = 8.79 Hz, C_{12}-H), 8.27-8.29 (m, 1H, C_7-H), 8.51 (s, 1H, O-CH=), 10.37 (s, 1H, CHO).

Anal. Calcd. for $C_{17}H_{10}O_3S$: C, 69.39; H, 3.40; S, 10.88. Found: C, 69.35; H, 3.43; S, 10.82.

3-Formyl-4*H*,5*H*-naphtho[1′,2′:5,6]thiopyrano[4,3-*b*]pyran-4-one (**VI**).

This compound was obtained as a yellow powder, mp 174-176° (99% yield); ms: m/z [M⁺] Found: 294.0352; Calcd. for $C_{17}H_{10}O_3S$: 294.0351; ^{1}H-nmr (deuteriochloroform): δ 3.95 (s, 2H, S-CH_2), 7.52 (d, 1H, J = 8.79 Hz, C_7-H), 7.53 (ddd, 1H, J = 8.52, 6.87, 1.37 Hz, C_{10}-H), 7.60 (ddd, 1H, J = 8.25, 6.87, 1.37 Hz, C_{11}-H), 7.83 (d, 1H, J = 8.79 Hz, C_8-H), 7.85 (dd, 1H, J = 8.25, 1.37 Hz, C_9-H), 8.25 (dd, 1H, J = 8.52, 1.37 Hz, C_{12}-H), 8.52 (s, 1H, O-CH=), 10.40 (s, 1H, CHO).

Anal. Calcd. for $C_{17}H_{10}O_3S$: C, 69.39; H, 3.40; S, 10.88. Found: C, 69.44; H, 3.38; S, 10.85.

3-Methyl-4*H*,5*H*-naphtho[1′,2′:6,5]thiopyrano[4,3-*b*]pyran-4-one (**XV**).

This compound was obtained as orange crystals, mp 154-156° (82% yield); ms: m/z [M⁺] Found: 280.0566; Calcd. for $C_{17}H_{12}O_2S$: 280.0558; ^{1}H-nmr (deuteriochloroform): δ 2.04 (d, 3H, J = 1.37 Hz, CH_3), 4.11 (s, 2H, S-CH_2), 7.58-7.60 (m, 2H, C_8-H, C_9-H), 7.71 (d, 1H, J = 8.79 Hz, C_{11}-H), 7.82 (q, 1H, J = 1.37 Hz, O-CH=), 7.83-7.86 (m, 1H, C_{10}-H), 7.88 (d, 1H, J = 8.79 Hz, C_{12}-H), 8.26-8.29 (m, 1H, C_7-H).

Anal. Calcd. for $C_{17}H_{12}O_2S$: C, 72.86; H, 4.28; S, 11.43. Found: C, 72.83; H, 4.32; S, 11.39.

3-Methyl-4*H*,5*H*-naphtho[1′,2′:5,6]thiopyrano[4,3-*b*]pyran-4-one (**XVI**).

This compound was obtained as a light yellow powder; mp 140-142° (94% yield); ms: m/z [M⁺] Found: 280.0570; Calcd. for $C_{17}H_{12}O_2S$: 280.0558; ^{1}H-nmr (deuteriochloroform): δ 2.07 (d, 3H, J = 1.37 Hz, CH_3), 3.95 (s, 2H, S-CH_2), 7.49 (ddd, 1H, J = 8.52, 6.87, 1.37 Hz, C_{10}-H), 7.50 (d, 1H, J = 8.52 Hz, C_7-H), 7.56 (ddd, 1H, J = 8.52, 6.87, 1.37 Hz, C_{11}-H), 7.78 (d, 1H, J = 8.52 Hz, C_8-H), 7.83 (dd, 1H, J = 8.52, 1.37 Hz, C_9-H), 7.85 (d, 1H, J = 1.37 Hz, O-CH=), 8.34 (dd, 1H, J = 8.52, 1.37 Hz, C_{12}-H).

Anal. Calcd. for $C_{17}H_{12}O_2S$: C, 72.86; H, 4.28; S, 11.43. Found: C, 72.79; H, 4.27; S, 11.47.

3-Chloromethyl-4*H*-naphtho[1,2-*b*]pyran-4-one (**XXIII**).

This compound was obtained as a light brown powder, mp 170-172° (68% yield); ms: m/z [M⁺] Found: 244.0299; Calcd. for $C_{14}H_9O_2Cl$: 244.0290; ^{1}H-nmr (deuteriochloroform): δ 4.62 (d, 2H, J = 0.82 Hz, CH_2Cl), 7.69 (ddd, 1H, J = 8.52, 6.87, 1.65 Hz, C_8-H), 7.73 (ddd, 1H, J = 8.24, 6.87, 1.37 Hz, C_9-H), 7.80 (d, 1H, J = 8.79 Hz, C_6-H), 7.95 (dd, 1H, J = 8.52, 1.37 Hz, C_7-H), 8.18 (d, 1H, J = 8.79 Hz, C_5-H), 8.30 (t, 1H, J = 0.82 Hz, O-CH=), 8.49 (dd, 1H, J = 8.24, 1.65 Hz, C_{10}-H).

Anal. Calcd. for $C_{14}H_9O_2Cl$: C, 68.71; H, 3.68; Cl, 14.52. Found: C, 68.84; H, 3.72; Cl, 14.33.

2-Chloromethyl-1*H*-naphtho[2,1-*b*]pyran-1-one (**XXIV**).

This compound was obtained as a light brown powder, mp 136-139° (67% yield); ms: m/z [M⁺] Found: 244.0279; Calcd. for $C_{14}H_9O_2Cl$: 244.0290; ^{1}H-nmr (deuteriochloroform): δ 4.64 (d, 2H, J = 0.83 Hz, CH_2Cl), 7.52 (d, 1H, J = 9.06 Hz, C_6-H), 7.64 (ddd, 1H, J = 8.24, 6.87, 1.37 Hz, C_8-H), 7.78 (ddd, 1H, J = 8.52, 6.87, 1.65 Hz, C_9-H), 7.92 (dd, 1H, J = 8.24, 1.65 Hz, C_7-H), 8.11 (d, 1H, J = 9.0 Hz, C_5-H), 8.16 (t, 1H, J = 0.83 Hz, O-CH=), 10.05 (dd, 1H, J = 8.52, 1.37 Hz, C_{10}-H).

Anal. Calcd. for $C_{14}H_9O_2Cl$: C, 68.71; H, 3.68; Cl, 14.52. Found: C, 68.73; H, 3.65; Cl, 14.42.

The Reaction of Dioxaborin Difluoride Complexes **III** or **IV** with DMTF in Acetic Anhydride.

Dimethylthioformamide (DMTF, 40 mmoles) was added dropwise to a mixture of **III** or **IV** (20 mmoles) with acetic anhydride (10 ml) under a nitrogen atmosphere and the mixture was stirred at 100° for 3 hours. After cooling, the crystalline solid which separated was collected and recrystallized from acetone to give **IX** or **X**.

2,2-Difluoro-4-(2-dimethylaminovinyl)-5*H*-naphtho[1′,2′:6,5]thiopyrano[3,4-*e*]-1,3,2-dioxaborin (**IX**).

This compound was obtained as a dark green powder, mp >300° (73% yield); ms: m/z [M⁺] Found: 358.0976; Calcd. for $C_{18}H_{16}F_2O_2BNS$: 358.0998; ^{1}H-nmr (deuteriochloroform): δ 2.15 (s, 3H, N-CH_3), 3.43 (s, 3H, N-CH_3), 3.92 (s, 2H, S-CH_2), 5.51 (d, 1H, J = 11.72 Hz, C*H*=CHN), 7.57-7.63 (m, 2H, C_8-H, C_9-H), 7.70 (d, 1H, J = 8.24 Hz, C_{11}-H), 7.85-7.88 (m, 1H, C_{10}-H), 8.01 (d, 1H, J = 8.24 Hz, C_{12}-H), 8.20-8.22 (m, 1H, C_7-H), 8.30 (d, 1H, J = 11.72 Hz, CH=C*H*N).

Anal. Calcd. for $C_{18}H_{16}F_2O_2BNS$: C, 60.33; H, 4.47; N, 3.91; S, 8.94. Found: C, 60.28; H, 4.50; N, 3.90; S, 8.89.

2,2-Difluoro-4-(2-dimethylaminovinyl)-5*H*-naphtho[1',2':5,6]thiopyrano[3,4-*e*]-1,3,2-dioxaborin (**X**).

This compound was obtained as orange crystals, mp 289-291° (84% yield); ms: m/z [M⁺] Found: 358.0983; Calcd. for $C_{18}H_{16}F_2O_2BNS$: 358.0998; ^{1}H-nmr (deuteriochloroform): δ 3.10 (s, 3H, N-CH_3), 3.33 (s, 3H, N-CH_3), 3.63 (s, 2H, S-CH_2), 5.28 (d, 1H, J = 11.72 Hz, C*H*=CHN), 7.39 (d, 1H, J = 8.30 Hz, C_7-H), 7.45 (ddd, 1H, J = 8.30, 6.84, 1.47 Hz, C_{10}-H), 7.57 (ddd, 1H, J = 8.30, 6.84, 1.47 Hz, C_{11}-H), 7.75 (d, 2H, J = 8.30 Hz, C_8-H, C_9-H), 8.25 (d, 1H, J = 11.72 Hz, CH=C*H*N), 8.82 (dd, 1H, J = 8.30, 1.47 Hz, C_{12}-H).

Anal. Calcd. for $C_{18}H_{16}F_2O_2BNS$: C, 60.33; H, 4.47; N, 3.91; S, 8.94. Found: C, 60.31; H, 4.52; N, 3.88; S, 8.92.

Attempted Reaction of **XIII** or **XIV** with DMTF in Acetic Anhydride.

Dimethylthioformamide (DMTF, 0.89 g, 10 mmoles) was added dropwise to a mixture of **XIII** (1.58 g, 5 mmoles) with acetic anhydride (10 ml) under a nitrogen atmosphere and the reaction mixture was heated at 100° for 3 hours. After cooling, the crystalline solid which separated was collected and washed with *n*-hexane. Compound **XV** (0.42 g, 30%) was obtained as insoluble crystals. The *n*-hexane soluble portion was dried over sodium sulfate and evaporated to give 0.36 g (24% yield) of 3-methyl-4*H*,5*H*-naphtho[1',2':6,5]thiopyrano[4,3-*b*]pyran-4-thione (**XVII**) as an orange powder, mp 216-218°; ms: m/z [M⁺] Found: 296.0316; Calcd. for $C_{17}H_{12}OS_2$: 296.0330; ^{1}H-nmr (deuteriochloroform): δ 2.29 (d, 3H, J = 1.10 Hz, CH_3), 4.57 (s, 2H, S-CH_2), 7.59-7.62 (m, 2H, C_8-H, C_9-H), 7.72 (d, 1H, J = 8.79 Hz, C_{11}-H), 7.85 (q, 1H, J = 1.10 Hz, O-CH=), 7.82-7.89 (m, 1H, C_{10}-H), 7.91 (d, 1H, J = 8.79 Hz, C_{12}-H), 8.27-8.30 (m, 1H, C_7-H).

Anal. Calcd. for $C_{17}H_{12}OS_2$: C, 68.92; H, 4.05; S, 21.62. Found: C, 68.96; H, 4.09; S, 21.58.

On the other hand, the *n*-hexane insoluble portion from the reaction of **XIV** with DMTF gave 0.46 g (31% yield) of 3-methyl-4*H*,5*H*-naphtho[1',2':5,6]thiopyrano[4,3-*b*]pyran-4-thione (**XVIII**) as a light yellow powder. The remainder of the *n*-hexane soluble material gave starting material, **XIV** (1.0 g, 63% yield). Thiopyranopyranone was not obtained.

3-Methyl-4*H*,5*H*-naphtho[1',2':5,6]thiopyrano[4,3-*b*]pyran-4-thione (**XVIII**).

This compound was obtained as orange crystals, mp 166-168°; ms: m/z [M⁺] Found: 296.0319; Calcd. for $C_{17}H_{12}OS_2$: 296.0330; ^{1}H-nmr (deuteriochloroform): δ 2.31 (d, 3H, J = 1.10 Hz, CH_3), 4.48 (s, 2H, S-CH_2), 7.50 (ddd, 1H, J = 8.51, 6.87, 1.37 Hz, C_{10}-H), 7.51 (d, 1H, J = 8.51 Hz, C_7-H), 7.57 (ddd, 1H, J = 8.51, 6.87, 1.37 Hz, C_{11}-H), 7.81 (d, 1H, J = 8.51 Hz, C_8-H), 7.85 (dd, 1H, J = 8.51, 1.37 Hz, C_9-H), 7.86 (q, 1H, J = 1.10 Hz, O-CH=), 8.28 (dd, 1H, J = 8.51, 1.37 Hz, C_{12}-H).

Anal. Calcd. for $C_{17}H_{12}OS_2$: C, 68.92; H, 4.05; S, 21.62. Found: C, 68.87; H, 4.07; S, 21.67.

The Treatment of Difluoride Dioxaborines (**IX** or **X**) with Hydrochloric Acid.

The solution of **IX** (4 mmoles) in THF (50 ml) was added dropwise to concentrated hydrochloric acid (20 ml) and the mixture was refluxed for 3 hours. The cold reaction mixture was neutralized with 10% sodium hydroxide and extracted with ether. The ether layer was dried over sodium sulfate and evaporated. The residual crystalline solid was recrystallized from *n*-hexane to give **VII**. In a similar manner, compound **X** was treated with hydrochloric acid solution to produce **VIII**.

4*H*,5*H*-Naphtho[1',2':6,5]thiopyrano[4,3-*b*]pyran-4-one (**VII**).

This compound was obtained as a yellow powder, mp 174-176° (75% yield); ms: m/z [M⁺] Found: 266.0382; Calcd. for $C_{16}H_{10}O_2S$: 266.0401; ^{1}H-nmr (deuteriochloroform): δ 4.08 (s, 2H, S-CH_2), 6.48 (d, 1H, J = 5.77 Hz, O-CH=C*H*), 7.58-7.62 (m, 2H, C_8-H, C_9-H), 7.72 (d, 1H, J = 8.79 Hz, C_{11}-H), 7.84-7.87 (m, 1H, C_{10}-H), 7.87 (d, 1H, J = 8.79 Hz, C_{12}-H), 7.88 (d, 1H, J = 5.77 Hz, O-C*H*=CH), 8.26-8.29 (m, 1H, C_7-H).

Anal. Calcd. for $C_{16}H_{10}O_2S$: C, 72.18; H, 3.76; S, 12.03. Found: C, 72.27; H, 3.79; S, 12.10.

4*H*,5*H*-Naphtho[1',2':5,6]thiopyrano[4,3-*b*]pyran-4-one (**VIII**).

This compound was obtained as a yellow powder, mp 157-158° (70% yield); ms: m/z [M⁺] Found: 266.0395; Calcd. for $C_{16}H_{10}O_2S$: 266.0401; ^{1}H-nmr (deuteriochloroform): δ 3.91 (s, 2H, S-CH_2), 6.54 (d, 1H, J = 5.77 Hz, O-CH=C*H*), 7.48 (d, 1H, J = 8.79 Hz, C_7-H), 7.49 (ddd, 1H, J = 7.96, 6.86, 0.82 Hz, C_{10}-H), 7.57 (ddd, 1H, J = 8.79, 6.86, 0.82 Hz, C_{11}-H), 7.78 (d, 1H, J = 8.79 Hz, C_8-H), 7.83 (dd, 1H, J = 7.96, 0.82 Hz, C_9-H), 7.88 (d, 1H, J = 5.77 Hz, O-C*H*=CH), 8.30 (dd, 1H, J = 8.79, 0.82 Hz, C_{12}-H).

Anal. Calcd. for $C_{16}H_{10}O_2S$: C, 72.18; H, 3.76; S, 12.03. Found: C, 72.21; H, 3.71; S, 12.08.

The Reaction of Thiopyranopyranones **VII**, **VIII**, **XV** or **XVI** with DMTF in Acetic Anhydride.

Dimethylthioformamide (DMTF, 10 mmoles) was added dropwise to a mixture of **VII** or **VIII** (5 mmoles) with acetic anhydride (10 ml) under a nitrogen atmosphere and the mixture was stirred at 100° for 3 hours. After cooling, the crystalline solid which separated was filtered and recrystallized from *n*-hexane to give **XI** or **XII**. In a similar reaction of **XV** or **XVI** with DMTF in acetic anhydride yielded **XVII** or **XVIII** in 52% or 49% yields, respectively.

4*H*,5*H*-Naphtho[1',2':6,5]thiopyrano[4,3-*b*]pyran-4-thione (**XI**).

This compound was obtained as orange crystals, mp 196-198° (83% yield); ms: m/z [M⁺] Found: 282.0191; Calcd. for $C_{16}H_{10}OS_2$: 282.0173; ^{1}H-nmr (deuteriochloroform): δ 4.48 (s, 2H, S-CH_2), 7.34 (d, 1H, J = 5.36 Hz, O-CH=C*H*), 7.62 (d, 1H, J = 5.36 Hz, O-C*H*=CH), 7.60-7.64 (m, 2H, C_8-H, C_9-H), 7.72 (d, 1H, J = 8.52 Hz, C_{11}-H), 7.84-7.89 (m, 1H, C_{10}-H), 7.89 (d, 1H, J = 8.52 Hz, C_{12}-H), 8.26-8.30 (m, 1H, C_7-H).

Anal. Calcd. for $C_{16}H_{10}OS_2$: C, 68.08; H, 3.55; S, 22.69. Found: C, 68.13; H, 3.57; S, 22.76.

4*H*,5*H*-Naphtho[1',2':5,6]thiopyrano[4,3-*b*]pyran-4-thione (**XII**).

This compound was obtained as orange crystals, mp 155-157° (68% yield); ms: m/z [M⁺] Found: 282.0150; Calcd. for $C_{16}H_{10}OS_2$: 282.0173; ^{1}H-nmr (deuteriochloroform): δ 4.38 (s, 2H, S-CH_2), 7.41 (d, 1H, J = 5.49 Hz, O-CH=C*H*), 7.50 (d, 1H, J = 8.52 Hz, C_7-H), 7.51 (ddd, 1H, J = 8.25, 6.86, 1.37 Hz, C_{10}-H), 7.58 (ddd, 1H, J = 8.25, 6.86, 1.37 Hz, C_{11}-H), 7.62 (d, 1H, J = 5.49 Hz, O-C*H*=CH), 7.81 (d, 1H, J = 8.52 Hz, C_8-H), 7.85 (dd, 1H, J = 8.25, 1.37 Hz, C_9-H), 8.26 (dd, 1H, J = 8.25, 1.37 Hz, C_{12}-H).

Anal. Calcd. for $C_{16}H_{10}OS_2$: C, 68.08; H, 3.55; S, 22.69. Found: C, 67.99; H, 3.55; S, 22.74.

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