The preparation of some thiochroman-3-ones and derivatives

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The use of 2,3-dihydrobenzo[*b*]thiophene-2,3-dione as a source of 2-mercaptophenylacetic acid permits a convenient preparation of 2-carboxymethylthiophenylacetic acid or derivatives. These undergo a Dieckmann cyclization to 3-acetoxybenzothiopyrans, which may be hydrolysed to thiochroman-3-ones. The further reactions of some of these are described.

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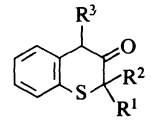
A partir de la dihydro-2,3-benzo[b]thiophènedione-2,3 on peut préparer l'acide *o*-mercaptophénylacétique permettant une synthèse convenable des acides *o*-carboxyméthylthiophénylacétiques ou de leurs dérivés. On obtient par la réaction de cyclisation de type Dieckmann des acétoxy-3-benzothiopyrrannes qui par hydrolyse conduisent aux thiochromannones-3. On décrit les réactions supplémentaires des quelques'uns de ces composés.

In contrast to thiochroman-4-ones and their derivatives (1) few derivatives of thiochroman-3-ones (1) are reported. The parent compound **1***a* may be made by a Dieckmann or modified Dieckmann cyclization of the diacid **2***a* or of derivatives (2, 3), or by photochemical rearrangement of the isomeric isothiochroman-4-one (2). This latter method was also applied to compounds bearing substituents in the aromatic ring, i.e. the 5-methyl and the 6-methoxy derivatives. In connection with another investigation we wished to prepare some examples of **1** bearing substituents in the heterocyclic ring as synthetic precursors of other heterocyclic systems. This work is reported below.

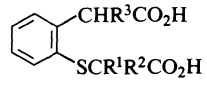
The diacids **2** may be approached in two ways, by an Arndt–Eistert homologation of ethyl 2-(carboxyphenylthioacetate) (**3**) (3), or by carboxyalkylation of 2-mercaptophenylacetic acid derivatives **4** (3). Our initial experiments using the former method to prepare a phenyl-substituted system were unsuccessful, and it appears that this method has limited value. Our experiments were therefore directed to the latter approach, i.e. from 2-mercaptophenylacetic acid (4). While this key acid may be made starting from 2-nitrophenylacetic acid (4), this approach limits the scope of the method. In fact a method starting from benzenethiol, via 2,3-dihydrobenzo[*b*]thiophene-2,3-dione (**5**) (5, 6), with certain modifications gives a very convenient preparation of the acid, as the dione **5** may be readily purified by extraction with base. This method is also capable of application to the preparation of other thiochroman-3-ones with substituents on the aromatic ring.

2-Mercaptophenylacetic acid (**4**) reacted with bromoacetic acid in base to provide the known



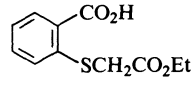
1

a $R^1 = R^2 = R^3 = H$
b $R^1 = CH_3$, $R^2 = R^3 = H$
c $R^1 = R^2 = CH_3$, $R^3 = H$
d $R^1 = Ph$, $R^2 = R^3 = H$
e $R^1 = COPh$, $R^2 = R^3 = H$
f $R^1 = R^2 = H$, $R^3 = CH_3$
g $R^1 = R^2 = H$, $R^3 = COPh$

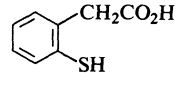


2

a $R^1 = R^2 = R^3 = H$
b $R^1 = CH_3$, $R^2 = R^3 = H$
c $R^1 = R^2 = CH_3$, $R^3 = H$
d $R^1 = Ph$, $R^2 = R^3 = H$



3



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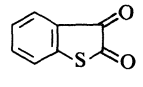

5

diacid **2***a*, previously prepared by hydrolysis of its diester (2). For cyclization to **1***a*, Mispelter *et al.* reported the use of acetic anhydride/sodium acetate, followed by aqueous sodium hydroxide, without reporting experimental conditions. In our hands, the treatment of the diacid afforded an oil, which had the properties of an enol-acetate of **1***a*. This compound was assigned the conjugated structure **6***a*, rather than the isomeric **7***a* on the following grounds.

The compound exhibited a 2H singlet at 3.59δ and a 1H singlet at 6.34δ, assigned respectively to the methylene and vinyl protons in **6***a*. Irradiation of the latter resonance produced a larger enhancement of the peak area of the aromatic protons than did the former, by a nuclear Overhauser effect,

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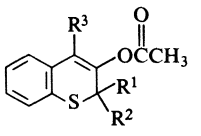
consistent with the structure **6***a*. In addition this structure is confirmed by comparison of its nmr spectrum with that of the 2-methyl derivatives **6***b*,*c* described below. For instance, the enol-acetate **6***c*, prepared by an unambiguous synthesis, exhibits no absorption in the region 3.59δ.

The hydrolysis of **6***a* to thiochroman-3-one (**1***a*) gave some problems, but eventually it was found that dilute hydrochloric acid in acetic acid gave satisfactory results.

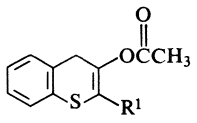
Likewise, treatment of **4** with ethyl-2-bromopropionate afforded the mono-ester **8***b*. This was not purified but was hydrolyzed directly to **2***b* which underwent cyclization by the above conditions to give an enol-acetate. In view of its similar spectral properties to **6***a* it is assigned the structure **6***b*, and mild acid hydrolysis gave 2-methylthiochroman-3-one (**1***b*). Also, reaction of **4** with 2-bromo-2-methylpropanoic acid afforded the acid **2***c* which cyclized to form the enol-acetate **6***c*. Hydrolysis of this afforded the ketone **1***c*.

The synthesis was then extended to produce the 2-phenyl compound **1***d*. Reaction of **4** with ethyl 2-bromophenylacetate gave the monoester **8***d* which on hydrolysis gave the diacid **2***d*. Cyclization of this afforded a mixture, which after chromatography and crystallization was separated into two components, a crystalline solid and an oil. Both of these had absorptions in the nmr corresponding to acetate methyl groups. The solid component also exhibited two singlets at 4.90 and 6.75δ, consistent with the 2- and 4-protons respectively in the enol acetate **6***d*. The other component could not be separated completely from **6***d*, but its nmr spectrum indicated a peak at 3.69δ which is consistent with the methylene protons in the isomeric enol acetate **7***b*. In contrast to the above cyclizations, i.e. to **6***a*,*b*,*c*, both enol-acetates in this case are conjugated and would be expected to be more comparable in stability.



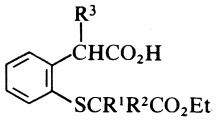
6

a $R^1 = R^2 = R^3 = H$
b $R^1 = CH_3$, $R^2 = R^3 = H$
c $R^1 = R^2 = CH_3$, $R^3 = H$
d $R^1 = Ph$, $R^2 = R^3 = H$



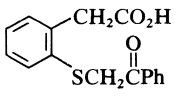
7

a R = H
b R = Ph



8

b $R^1 = CH_3$, $R^2 = R^3 = H$
d $R^1 = Ph$, $R^2 = R^3 = H$



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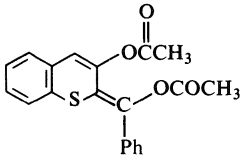
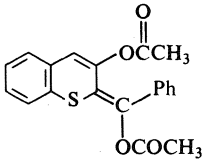


10*a*



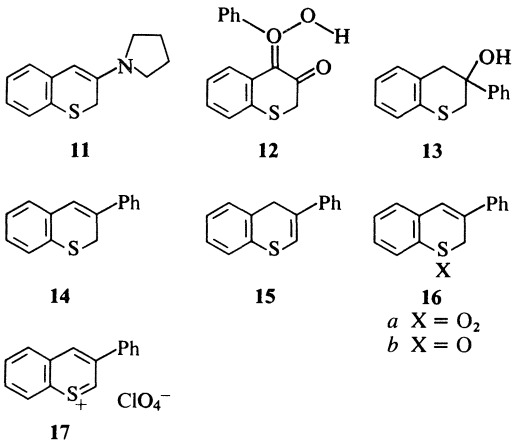
10*b*

While the enol-acetate **6***d* hydrolysed cleanly to the ketone **1***d*, the isomer **7***d* gave **1***d* along with highly colored material. Consideration of hydrolysis mechanisms indicates that while for **6***d* the production of **1***d* is the most reasonable reaction, for **7***d* a competing reaction involving initial protonation at C-3 could lead to decomposition products.

When 2-phenacylthiophenylacetic acid (**9**), prepared by treatment of **4** with phenacyl bromide, was heated with the acetic anhydride/sodium acetate mixture, a dark green solution was obtained. This appeared to possess two main components, one of which was obtained as pale yellow crystals, whose analysis and properties were consistent with the *bis* enol-acetate **10***a* of the diketone **1***e*. The nmr of this exhibited two CH_3 singlets in the region 1.20 and 2.13δ. While the latter is in the usual range for an acetate methyl group, the former is not. However, it may be that one acetate is shielded by the extra aromatic ring. The other component of the mixture was a dark yellow oil but repeated chromatography failed to separate this from impurities. Tentatively it is assigned the structure of a geometrical isomer of **10***a*, i.e. **10***b*. A strongly colored blue component of the mixture was present in only trace amounts.

Attempted hydrolysis of the *bis* enol-acetate **10***a* gave only polymeric and highly colored material. This is not unexpected in view of its 1,3-diene structure.

The ketone **1***a* reacted smoothly with pyrrolidine to form a crystalline enamine, to which was assigned the structure **11**. The nmr spectrum was consistent with this structure rather than the isomeric nonconjugated structure. Reaction with methyl iodide followed by hydrolysis afforded a methyl derivative of **1***a* in good yield. This was not identical to the methyl derivative **1***b* prepared above, confirming its identity as 4-methylbenzothiopyran-3-one (**1***f*). Treatment of **11** with benzoyl chloride afforded, after hydrolysis, 4-benzoylthiochroman-3-one (**1***g*). Since this exhibited a two proton singlet at 3.36δ, and an acidic proton at 16.3δ, it appears to exist as an enolic tautomer, possibly structure **12**.

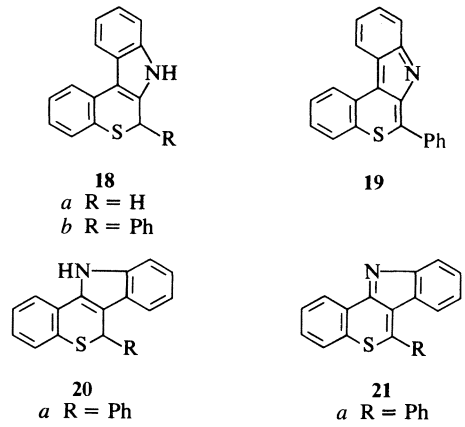


In **1***a* the 4-protons appear to be the more acidic compared to the 2-protons since on treatment with deuterium oxide in the presence of sodium carbonate only the 4-protons were exchanged as determined by nmr. Subsequent treatment with aqueous sodium carbonate regenerated the original spectrum.

When **1***a* was treated with phenylmagnesium bromide it was converted to the alcohol **13**, which dehydrated to 3-phenyl-2-*H*-1-benzothiopyran (**14**) on treatment with acid. This structure is favored over the isomeric structure **15** in view of the similarity of its nmr spectrum to 6-chloro-3-phenyl-2*H*-1-benzothiopyran (7). The compound **14** has been made (8) but no data are reported. Also, treatment with two equivalents of *m*-chloroperoxybenzoic acid afforded a sulfone **16***a*. The differences in chemical shifts of the methylene group in **14** and **16***a* are consistent with those reported for methylene protons adjacent to a sulfide and to a sulfonyl group (9). Oxidation with one equivalent afforded a sulfoxide **19***b*. When this was treated with acetic acid and perchloric acid it produced the known (10) 3-phenylbenzothiopyrylium perchlorate (**17**), although in low yield. The first two stages in a Pummerer type rearrangement of **16** would produce **17**.

While most of the aromatic protons in **12** absorbed in the region δ 7.1–7.6, an absorption at δ 6.73 was also evident, which we attribute to shielding of the 5- and/or 6-protons of the thiopyran ring by the phenyl substituent. The structure **12** has some similar steric features to 4-phenylphenanthrene because of the strong hydrogen bonding of the hydroxyl and carbonyl functions and in 4-phenylphenanthrene and derivatives similar chemical shifts have been observed (11).

The conversion of **1***a* to the condensed indole **18***a*, via a Fischer-type indolization of its phenylhydrazone is reported (2). Likewise **1***d* was converted to its phenylhydrazone which cyclized to the indole **18***b*. The related isomeric dihydrothiopyrano-[4,3-*b*]indoles **20** may be converted into the more conjugated derivatives **21** by dehydrogenation (12, 13) and this was also found for the phenyl-substituted compound **20***a*, prepared by cyclization of 2-phenylthiochromone phenylhydrazone, which formed **21***a* on treatment with chloranil. Under these conditions **18***b* could not be further dehydrogenated. Like **18***a*, **18***b* underwent atmospheric oxidation, but no definite products could be determined.



Experimental

Unless otherwise stated, ^{1}H nmr spectra were obtained in deuteriochloroform solution using tetramethylsilane as an internal standard, on a Varian model E.M. 360 spectrometer. Unless otherwise given, nmr spectra are summarized in Table 1. Mass spectra were obtained on a Finnegan model 1015 spectrometer, and ir spectra on a Perkin Elmer model 337 spectrophotometer. Thick layer chromatography (tlc) was performed on "Camag" Silica gel type D.S.F.S. supplied by Terochem Laboratories, and column chromatography (cc) on 60–200 mesh silica gel supplied by Davison Chemical. Solutions were dried over anhydrous magnesium sulfate.

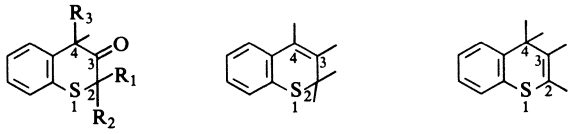
2-Mercaptophenylacetic acid (4)

The starting 2,3-dihydrobenzo[*b*]thiophene-2,3-dione was prepared by the method of Papa *et al.* (5), with the following modifications. The crude product obtained by cyclization of 2-oxo(2-mercaptophenyl)acetyl chloride was dissolved in 20% aqueous sodium hydroxide solution. Impurities (mainly phenyl thioloxalate) were removed by extraction with dichloromethane. Acidification of the cooled solution with concentrated hydrochloric acid gave 2,3-dihydrobenzo[*b*]thiophene-2,3-dione as orange prisms, mp 119–121°C (lit. (5) mp 120–121°C). No further purification was necessary. Conversion of this to **4** was effected by the method of Glauert *et al.* (6). The material was used within one day to minimize spontaneous cyclization to 2,3-dihydrobenzo[*b*]thiophene-2-one.

2-Carboxymethylthiophenylacetic acids (2)

2-Mercaptophenylacetic acid (**4**) was treated with an equiva-

TABLE 1. Proton chemical shifts (δ) in thiochroman-3-ones (**1**), 2-*H*-1-benzothiopyrans, and 4-*H*-1-benzothiopyrans



1 **6, 10, 11, 12, 14, 16** **7**

Compound	C-2	C-4	Aromatic	
1*a*	3.33s	3.75s*	7.03–7.07m	
1*b*	3.43q	3.75s	7.10–7.55m	1.45 (d, the 2-methyl protons)
1*c*	—	3.70s	7.06–7.45m	1.35 (s, the methyl protons)
1*d*	4.53	3.90	7.15–7.33	—
1*f*	3.37s	3.79q	7.10–7.47m	1.55 (d, the methyl protons)
6*a*	3.59s	6.34s	7.00–7.61m	2.21 (s, acetate methyl)
6*b*	3.60q	6.32s	6.95–7.50m	1.40 (d, the 2-methyl group); 2.20 (s, the acetate methyls)
6*c*	—	6.17s	6.91–7.43m	1.45 (s, the 2-methyl group) 2.18 (s, the acetate methyl)
6*d*	4.90s	6.75s	7.19–7.41m	2.04 (s, the acetate methyl)
7*b*	—	3.69s	7.05–7.50m	1.95s (the acetate methyl)
10*a*	—	6.25s	7.09–7.30m	1.25s, 2.17s (the acetate methyl)
10*b*	—	6.32	7.05–7.42m	2.15s, 2.21s (the acetate methyl)
11	3.52s	5.30s	6.32–7.31m	1.66–2.0m (β-pyrrolidine protons) 3.05–3.40 (s, the enolic proton)
12	3.52s	—	6.60–7.61m	16.40 (s, the enolic proton)
14	3.73s	6.72s	7.05–7.49m	
16*a*	4.27s	6.97s	7.33–7.60m	
18*b*	5.43	—	7.10–8.25	(m, all other protons)

*On treatment with D_2O, Na_2CO_3 these protons rapidly exchanged.

TABLE 2. Preparation of 2-carboxymethylthiophenylacetic acids (**2**)

Compound	Yield %	Melting point °C	Formula	Analysis Calcd. % C	Calcd. % H	Calcd. % S	Found % C	Found % H	Found % S
2a	73	185–186*	$C_{10}H_{10}O_4S$	—	—	—	—	—	—
2b	64	154–155	$C_{11}H_{12}O_4S$	55.00	5.00	13.35	54.80	5.05	13.10
2c	51	141–142	$C_{12}H_{14}O_4S$	56.69	5.51	12.60	56.83	5.42	12.58
2d	85	197–198	$C_{16}H_{14}O_4S$	63.58	4.64	10.59	63.37	4.81	10.37

*Literature (2) mp 186°C.

lent quantity of the appropriate α-haloacid or ester[2] in ethanol containing two equivalents of sodium ethoxide. The solutions were heated under reflux for 1 h under nitrogen, then the solvent was evaporated and the residues were dissolved in aqueous 2 *M* sodium hydroxide solution. This was heated at 100°C (steam bath) for 1 h. After cooling, the mixtures were acidified, and the products collected and recrystallized from a hexane – ethyl acetate 1:1 mixture. Results are summarized in Table 2.

2-Phenacylthiophenylacetic acid (9)

2-Mercaptophenylacetic acid (1.68 g, 0.01 mol) was added to a solution of ethanol (50 mL) containing sodium (0.23 g, 0.01 mol). To the solution was added phenacyl bromide (1.99 g, 0.01 mol) and the mixture was let stand 3 h at room temperature. The ethanol was evaporated *in vacuo* and the residue treated with dilute hydrochloric acid. The liberated oily acid was extracted with chloroform which on evaporation gave an oil which was chromatographed (cc) on silica gel using a benzene–chloroform–methanol 9:6:1 mixture as an eluent. After a yellow forerun a band was obtained which on evaporation yielded the desired ketoacid **9** as a pale yellow oil which crystallized on standing under carbon disulfide and was recrystallized from toluene as pale yellow prisms, mp 116°C (73%). The nmr spectrum in CD_3OD, δ: 3.81, 4.15 (two CH_2 singlets, the methylene protons), 7.10–7.95 (9H bands, the aromatic protons). The mass spectrum, M^+, found: 286, M calcd.: 286. *Anal.* calcd. for $C_{16}H_{14}O_3S$: C 67.13, H 4.89, S 11.19%; found: C 67.36, H 5.03, S 10.93%. Further elution of the column gave small quantities of another yellow oil. This was not examined further.

3-Acetoxy-2H-1-benzothiopyran (6a)

A mixture of **2***a* (4.52 g, 0.02 mol) and anhydrous sodium acetate (4.5 g) in acetic anhydride (50 mL) was heated under reflux under nitrogen for 15 min. The solvent was removed *in vacuo*, the residue treated with sodium carbonate solution and extracted with ether. The dried ether extract on evaporation gave a yellow oil which was distilled *in vacuo*, bp 118–120°C at

[2]The use of haloacids or haloesters gave comparable results. Use was determined simply by their availability.

TABLE 3. Preparation of thiochroman-3-ones (**1**) by hydrolysis of enol acetates **6** or **7**

Compound	Starting material	Yield %	Boiling (melting) point °C	Formula	Analysis Calcd. % C	Calcd. % H	Calcd. % S	Found % C	Found % H	Found % S
1*a** *	**6***a*	82	115–120 0.9 Torr	C_9H_8OS	—	—	—	—	—	—
1*b*‡	**6***b*	85	110 0.5 Torr	$C_{10}H_{10}OS$	67.40	5.00	17.95	67.50	5.45	17.60
1*c*§	**6***c*	94	104–106 0.4 Torr	$C_{11}H_{12}OS$	68.75	6.25	16.67	68.83	5.98	16.63
1*d*†	**6***d*	91	117–119	$C_{15}H_{12}OS$	75.00	5.00	13.33	75.00	5.03	13.66
1*d*	**7***b*	51	117–119	$C_{15}H_{12}OS$	75.00	5.00	13.33	75.00	5.03	13.66

*The ir spectrum 1723 cm^{-1} (C=O str.).
†The ir spectrum 1711 cm^{-1} (C=O str.), no OH absorption.
‡The ir spectrum 1720 cm^{-1} (C=O str.).
§The ir spectrum 1721 cm^{-1} (C=O str.).

0.9 Torr (82%). The ir spectrum (film): 1765 cm^{-1} (C=O str.). The mass spectrum, M^+, found: 206, M calcd.: 206. *Anal.* calcd. for $C_{11}H_{10}SO_2$: C 61.11, H 4.63, S 14.81%; found: C 61.18, H 4.52, S 15.05%.

*3-Acetoxy-2-methyl-2*H*-1-benzothiopyran (**6**b)*

The cyclization of **2***b* was performed as above. The compound **6***b* was obtained as a pale yellow oil, bp 120°C at 0.2 Torr (85%). The ir spectrum (film): 1775 cm^{-1} (C=O str.). The mass spectrum, M^+, found: 220, M calcd.: 220. This material was not analysed.

*3-Acetoxy-2,2-dimethyl-2*H*-1-benzothiopyran (**6**c)*

The cyclization of **2***c* was performed as above. Examination by tlc showed a mixture of two main products, identified as the enol acetate **6***c* and the ketone **1***c*. This material was not analysed. The yield, estimated as ketone, was 76%.

*3-Acetoxy-2-phenyl-2*H*-1-benzothiopyran (**6**d)*

The cyclization was performed as above except with a reaction time of 1 h. Work-up afforded a yellow oil which was examined by column chromatography using a hexane–ether 7:3 mixture as an eluent. The first major fraction eluted gave on evaporation an oil which slowly partly crystallized and was recrystallized from methanol as pale yelow needles, mp 108–109°C (40%). The ir spectrum (liquid paraffin mull): 1773 cm^{-1} (C=O str.). The mass spectrum, M^+, found: 266, M calcd.: 266. *Anal.* calcd. for $C_{17}H_{14}SO$: C 76.69, H 5.26, S 12.03%; found: C 76.81, H 5.34, S 11.99%.

Evaporation of the methanol mother liquors afforded a viscous oil which appears to be a mixture of **6***d* and what is tentatively assigned the 3-acetoxy-2-phenyl-4*H*-1-benzothiopyran structure (**7***b*); yield 28%. This material was not analysed.

Further elution from the chromatogram yielded traces of a highly fluorescent yellow material.

*Cyclization of 2-phenacylthiophenylacetic acid (**9**)*

The acid (0.268, 1 mmol) in acetic anhydride (10 mL) and anhydrous sodium acetate (0.3 g) was refluxed 20 min. The mixture rapidly became dark green. The solution was treated cautiously with water (10 mL) and cooled. An ether extract was washed with water, then with dilute sodium carbonate solution, dried, and evaporated to give a dark green oil. This was examined by thin layer chromatography using a benzene–chloroform–methanol 8:2:1 mixture as an eluent. Two main yellow bands were obtained with an intense blue band between. Repeated chromatography afforded the first band reasonably pure and this crystallized from methanol as pale yellow needles mp 157–159°C. This is assigned the structure **10***a* (31%). The ir spectrum: 1765 cm^{-1} (C=O str.). The mass spectrum, M^+, found: 352, M calcd.: 352. *Anal.* calcd. for $C_{20}H_{16}SO_4$: C 68.12, H 4.56, S 9.09%; found: C 68.35, H 4.31, S 8.93%.

The second yellow band could not be purified properly and was obtained as viscous yellow oil, tentatively identified as **10***b*. The blue material was present only in trace amounts.

*Hydrolyses of 3-acetoxybenzothiopyrans to thiachroman-3-ones **1**a–d*

The enol acetates (1 g) in 60% aqueous acetic acid (20 mL) containing hydrochloric acid (0.1 mL) were refluxed for 6 h under nitrogen. The mixture was diluted with water (40 mL) and ether extracted. The extracts were washed with water, saturated sodium carbonate, dried, and evaporated to give the ketones which were either purified by distillation *in vacuo* or recrystallization.

The results are summarized in Table 3.

*Preparation of 3-pyrrolidino-2-*H*-1-benzothiopyran (**11**)*

A mixture of thiochroman-3-one (1 g), pyrrolidine (2 mL), and *p*-toluenesulfonic acid (5 mg) was heated in benzene (40 mL) under nitrogen for 4 h. Water was removed by continuous azeotropic distillation. The solvent was removed and the product crystallized from hexane as pale yellow plates (91%), mp 95–96°C. The mass spectrum, M^+, found: 217, M calcd.: 217. *Anal.* calcd. for $C_{13}H_{15}NS$: C 71.90, H 6.90, N 6.45, S 14.75%; found: C 71.60, H 6.81, N 6.40, S 14.55%.

*4-Methylthiochroman-3-one (**1**f)*

The enamine **11** (2.17 g, 0.01 mol) was dissolved in iodomethane (10 mL) and the solution kept at 20°C for 16 h. The solvent was removed, 5% dilute aqueous acetic acid (20 mL) added, and the mixture warmed at 100°C for 1/2 h. After cooling, the mixture was extracted with dichloromethane (3 × 30 mL). The washed and dried extracts on evaporation gave an oil which was purified by distillation *in vacuo*, bp 105–106°C at 0.4 Torr (63%). The ir spectrum (film): 1720 cm^{-1} (C=O str.). The mass spectrum, M^+, found: 178, M calcd.: 178. *Anal.* calcd. for $C_{10}H_{10}OS$: C 67.41, H 5.62, S 17.95%; found: C 67.45, H 5.40, S 17.80%.

*4-Benzoylthiochroman-3-one (**1**g)(**12**)*

The enamine **11** (0.434 g, 2 mmol) and benzoyl chloride (0.280 g, 2 mmol) in methylene chloride (20 mL) were refluxed 4 h. The solvent was removed and the crystalline material refluxed 1/2 h with 5% dilute hydrochloric acid (10 mL). The mixture was extracted with hexane and the solution was shaken with saturated aqueous cupric acetate solution. The copper complex was collected, and decomposed in dilute sulfuric acid. Final

purification was effected by chromatography in benzene. Pale yellow needles, mp 118–120°C, were obtained on evaporation (63%). The ir spectrum: 1597 cm^{-1} (C=O str., strongly hydrogen bonded), 2650–3300 (OH str., hydrogen bonded). The mass spectrum, M^+, found: 268, M calcd.: 268. *Anal.* calcd. for $C_{16}H_{12}O_2S$: C 71.64, H 4.48, S 11.96%; found: C 71.39, H 4.61, S 12.07%.

*Preparation of 3-phenylthiochroman-3-ol (**13**)*

Into a solution of thiochroman-3-one (**1***a*) (1.64 g, 10 mmol) in anhydrous ether (10 mL) was dropped the equivalent quantity of phenyl magnesium bromide in ether (20 mL). An immediate reaction was evident. After 10 min the solution was worked up by dilution with dilute hydrochloric acid and extraction with ether. The dried extracts on evaporation gave a yellow oil which was purified by chromatography using a benzene–methanol 20:1 mixture as an eluent. A virtually colorless oil was obtained (91%). The nmr spectrum δ: 2.60–3.50 (5H bands, the two diastereotopic methylene and the hydroxy protons), 6.86–7.52 (9H bands, the aromatic protons). The mass spectrum, M^+, found: 242, M calcd.: 242. *Anal.* calcd. for $C_{15}H_{14}OS$: C 74.38, H 5.78, S 13.22%; found: C 74.41, H 5.69, S 12.93%.

*Preparation of 2-phenyl-2*H*-1-benzothiopyran (**14**)*

A solution of **13** (0.242 g, 1 mmol) in toluene (10 mL) with *p*-toluenesulfonic acid (10 mg) was refluxed 1 h. Evaporation gave a pale brown oil which was purified by chromatography on silica gel with benzene as an eluent and distillation *in vacuo* (81%). The mass spectrum, M^+, found: 224, M calcd.: 224. *Anal.* calcd. for $C_{15}H_{12}S$: C 80.35, H 5.36, S 14.29%; found: C 80.62, H 5.42, S 13.95%.

*3-Phenyl-2*H*-1-benzothiopyran-*S,S*-dioxide (**16**a)*

This was made from **14** by oxidation with two equivalents of *m*-chloroperoxybenzoic acid in acetone. After 5 min the acetone solution was diluted with water and extracted with chloroform. The extract was washed with dilute sodium hydroxide solution, dried, and evaporated to give a colorless oil which was purified by chromatography (tlc) using benzene as an eluent (86%). The mass spectrum, M^+, found: 256, M calcd.: 256.

*3-Phenylthiopyrylium perchlorate (**17**)*

The thiopyran **14** was treated with one equivalent of *m*-chloroperoxybenzoic acid in acetone and worked up as above. The pale oil resulting was dissolved in acetic acid, warmed briefly, and to it added perchloric acid. The yellow solution on dilution with ether gave **20** as pale yellow prisms, mp 151°C (lit. (12) mp 151°C) (20%).

*2-Phenyl-2*H*-1-benzothiopyrano[3,4-*b*]indole (**18**b)*

2-Phenylthiochroman-3-one (240 mg, 1 mmol) was treated with a slight excess of phenylhydrazine hydrochloride and sodium acetate in ethanol. After refluxing 15 min the cooled mixture was poured into water. The yellow precipitate was collected and washed with water. A small sample crystallized from ethanol afforded yellow microcrystals, mp 124–127°C. This material was dissolved in acetic acid (10 mL), saturated with hydrogen chloride, and refluxed 45 min. The mixture was poured into water and extracted with ethyl acetate (3 × 30 mL). The washed and dried extracts on evaporation gave a dark red oil which was chromatographed (cc) using a hexane–ether 1:1 mixture as an eluent. The product was obtained as pale yellow microcrystals, mp 146–147°C from hexane (56%). These turned red on standing in air. The mass spectrum, M^+, found: 313, M calcd.: 313. *Anal.* calcd. for $C_{21}H_{15}NS$: C 80.51, H 4.79, N 4.47, S 10.22%; found: C 80.32, H 4.03, N 4.51, S 10.25%.

*2-Phenyldihydrobenzothiopyrano[4,3-*b*]indole (**20**)*

This was prepared as **2** above, starting from 2-phenylthiochroman-4-one (14). Yellow needles, mp 182–184°C, were obtained on recrystallization from methanol (81%). The mass spectrum, M^+, found: 313, 312; M calcd.: 313. *Anal.* calcd. for $C_{21}H_{15}NS$: C 80.51, H 4.79, N 4.47, S 10.22%; found: C 80.63, H 5.01, N 4.48, S 10.39%.

*2-Phenylbenzothiopyrano[4,3-*b*]indole (**21**)*

A mixture of the dehydro compound **23**, (0.313 g, 1 mmol) and chloranil (0.3 g) in ethyl acetate (20 mL) was heated under reflux 1 h. The solvent was removed *in vacuo* and the residue chromatographed (tlc) on silica gel using an ethyl acetate – hexane 2:1 mixture as an eluent. The product was obtained as orange needles, mp 210–212°C from ethyl acetate (92%). The mass spectrum, M^+, found: 311, M calcd.: 311. *Anal.* calcd. for $C_{21}H_{13}NS$: C 81.03, H 4.18, N 4.50, S 10.29%; found: C 81.11, H 4.21, N 4.36, S 10.03%.

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