Synthesis of some thiochromeno[4,3-*c*]- and [3,4-*c*]-pyrazoles

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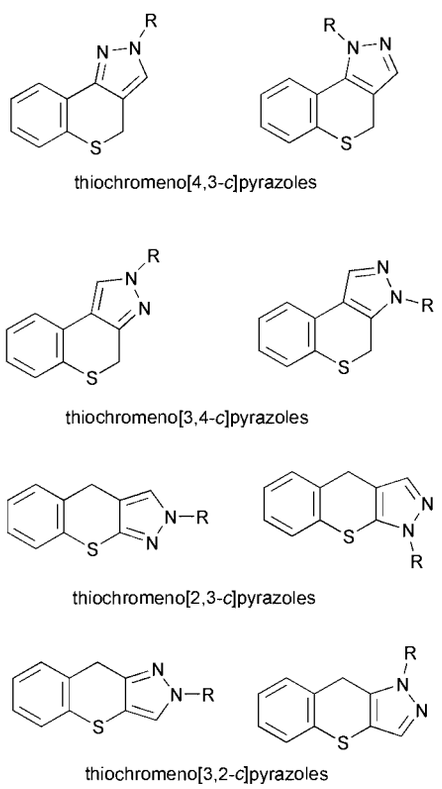
Reaction of 3-hydroxymethylene- and 3-cyanomethylene-thiochroman-4-ones with various hydrazine derivatives affords 4*H*-thiochromeno[4,3-*c*]pyrazoles. The novel isomeric thiochromeno[3,4-*c*]pyrazoles result when 4-(dimethylaminomethylene)thiochroman-3-ones react with methyl- and phenyl-hydrazines. Acidic hydrolysis of 3-(dimethylhydrazonoethylidene)-2,2,6-trimethylthiochroman-4-one yields the 3-cyanomethylene-thiochroman-4-one. Formation of 6-chloro-3-hydroxymethylenethiochroman-4-one is accompanied by a thiochroman-3-yl(oxothiochromen-3-yl)methane derivative produced through a rearrangement–carbocation interception sequence. A 3-isopropenylthiochromenone, obtained by the acid promoted rearrangement of a 3-hydroxymethylenethiochroman-4-one, undergoes Diels–Alder cycloadditions to provide a new route to thioxanthenones.

There are four possible modes of fusion of the pyrazole ring to the thiochromene unit. Each of these fused systems can exist in two possible tautomeric forms leading to eight isomers in all (Scheme 1, R = H). The synthesis of the linear thiochromeno-



Scheme 1

[2,3-*c*]-[1] and [3,2-*c*]-pyrazole[2] ring systems has attracted little interest. Much greater attention has been directed towards the synthesis of the thiochromeno[4,3-*c*]pyrazole ring system[3a–j] probably as a consequence of the ready availability of suitable 1,3-dicarbonyl precursors. Only the synthesis of the thiochromeno[3,4-*c*]pyrazole ring system remains undocumented to date.

Pyrazoles have received much attention since the ring system is readily accessible and exhibits diverse properties.[4a–e] There is also considerable interest in the saturated pyrazolines.[5]

The synthesis of pyrazoles is conveniently achieved by the condensation of a hydrazine with a 1,3-difunctional compound. A 1,3-diketone is the classical 3-atom synthon, but a wide variety of compounds with 1,3-disposed electrophilic centres has been employed, including β-keto esters, aldehydes and nitriles and substituted α,β-unsaturated ketones.[4e] The principal drawback of this method is that unsymmetrical 1,3-diketones can give rise to two isomeric products, a feature which has been thoroughly discussed,[4d] although the reaction is often regiospecific.

We have previously described the synthesis of some fused nitrogen-containing thiochromene heterocyclic systems *e.g.* thiochromeno[4,3-*b*]pyrroles,[6] thiochromeno[3,4-*c*][1,2]diazeto-[1,2-*a*][1,2,4]triazoles,[7] thiochromeno[3,4-*b*]quinoxalines[8] and we now report our results on the synthesis of some angularly fused thiochromeno-pyrazoles and -dihydropyrazoles.

Discussion

The most efficient route to generate a 1,3-dicarbonyl system from a thiochroman-4-one unit relies upon the base catalysed condensation of thiochroman-4-one with ethyl formate to afford 3-formylthiochroman-4-one, which exists exclusively as its 3-hydroxymethylene tautomer.[9] Application of this methodology to several substituted thiochroman-4-ones **1**[10,11] gave a range of 3-hydroxymethylenethiochroman-4-ones **2** as bright yellow oils in good yield (Scheme 2).

The structure of these compounds was confirmed from their ^{1}H NMR spectra which exhibited a low field, D_2O exchangeable, singlet for the hydroxy proton at *ca.* 15.5 ppm. The alkenyl proton routinely appeared as a broad singlet within the range 8.3–8.6 ppm, though in certain cases coupling to the hydroxy proton ($J \sim 7$ Hz) was observed (*e.g.* **2**, R = Me, X = H). Apart

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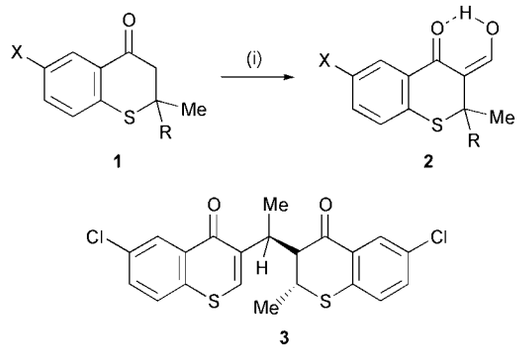


Scheme 2 *Reagents and conditions*: (i) NaOMe, HCO_2Et, PhMe, RT.

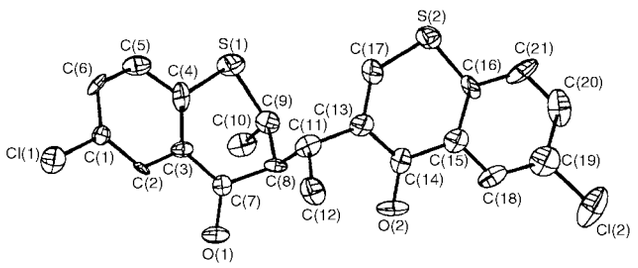


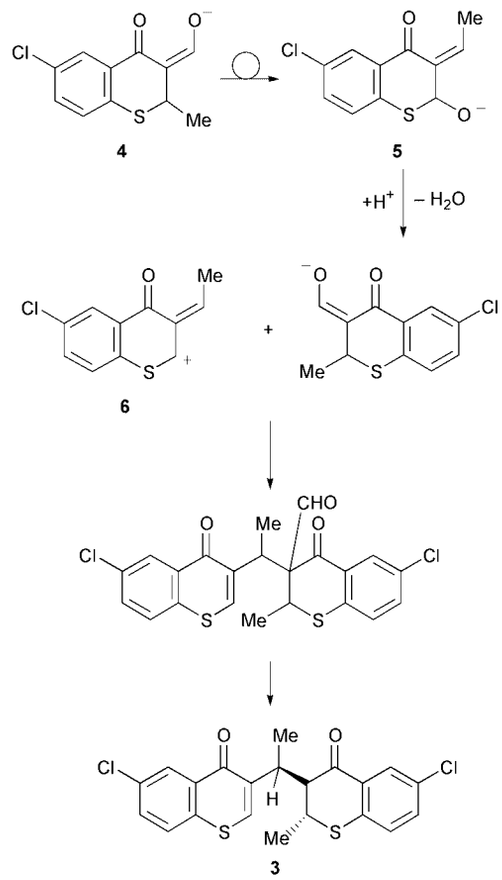
Fig. 1 X-Ray crystallography structure of **3**.

from the absence of the signals from the C-3 methylene protons, the remainder of the spectrum was very similar to that of the corresponding thiochroman-4-ones.[11]

A considerable quantity of a crystalline by-product **3** was obtained from the condensation of 6-chloro-2-methylthiochroman-4-one (**1**, R = H, X = Cl) with ethyl formate. Comparison of the integrals of the aromatic and aliphatic protons in the ^{1}H NMR spectrum of this compound suggested a dimeric structure that incorporated the 6-chlorothiochroman-4-one unit. Multiplets at 8.01, 7.34 and 7.13 ppm show a remarkable resemblance to those of the starting thiochroman-4-one. The chemical shift of the double doublet at 8.52 ppm and the singlet at 7.87 ppm are typical of H-5 and of H-2 respectively in the thiochromenone system.[12]

The presence of the thiochromenone and thiochromanone systems was also established by ^{13}C NMR spectroscopy. The low field signals at 177.7 and 194.7 ppm are assigned to the thiochromenone and thiochroman-4-one carbonyl carbon atoms respectively and compare favourably with literature values.[13] The infrared spectrum of this compound exhibits a band at 1675 cm^{-1}, typical of the carbonyl group in thiochroman-4-one and a band at 1610 cm^{-1}, which may be tentatively assigned to the thiochromenone carbonyl group, though the carbonyl stretching frequency for thiochromenones usually falls within the higher energy range 1620–1665 cm^{-1}.[14] From this spectroscopic study and X-ray crystallography (Fig. 1),[15] the structure of the dimer was established as **3**. Dimeric compounds of this type have been reported from the related oxygen heterocycles.[16a–d]

The formation of **3** is thought to proceed by protonation, on acidic work-up, of the anion **5** derived from a retro-Michael reaction of **4**, which prompts elimination of water to afford the allylic carbocation **6**. Interception of **6** by the nucleophilic C-3 carbon of a second molecule of hydroxymethylene ketone and hydrolysis of the non-enolisable β-oxoaldehyde group under the prevailing reaction conditions affords the product **3** (Scheme 3). Although it has three stereogenic centres we observed only a single diastereoisomer of the dimer **3** (Fig. 1). Thus, the substituents in the thiochromanone ring possess a *trans*-(*pseudo* diaxial) disposition, whilst the substituents about the C-8–C-11 bond (crystallographic numbering) have (relative) *u* stereochemistry (*i.e.* 8*S**11*R**). It is probable that the *trans*-thiochromanone moiety is derived *via* addition of **6** to the least



Scheme 3

hindered face of **4**, although epimerisation following hydrolysis of the β-oxoaldehyde intermediate cannot be precluded.

It is worthy of note that the rearrangement of the related 3-hydroxymethylenechroman-4-ones to 3-alkenylchromenones by heating in pyridine containing 4-TsOH has been reported.[17] We have found that such a rearrangement can be effected by stirring the 3-hydroxymethylenethiochroman-4-one (**2**, X = R = Me) in $MeSO_3H$ at room temperature to afford the 3-isopropenylthiochromenone **7** in reasonable yield (56%). Evidence for the rearrangement of **2** (X = R = Me) to **7** was obtained from ^{1}H NMR and infrared spectroscopy; H-5 resonates at *ca.* 8.4 ppm and the carbonyl stretch appears at 1618 cm^{-1}, values appropriate for the thiochromenone ring system.[12] This work constitutes the first report of such a rearrangement sequence in the thiochroman-4-one series.

It was thought that **7** should behave as an efficient 1,3-diene in cycloaddition reactions leading to a new synthesis of the thioxanthenone nucleus. Thus, heating a solution of **7** in xylene containing DMAD resulted in the formation of a complex reaction product from which the fully unsaturated thioxanthenone **8** was isolated in modest yield (34%) by column chromatography (Scheme 4). The ^{1}H NMR spectrum of **8** displayed the expected methyl ester signals at δ 3.95 and 4.04 and methyl signals at δ 2.47 (7-Me) and 2.91 (1-Me). Cycloaddition of **7** with *N*-methylmaleimide, also gave, remarkably, the fully aromatic thioxanthenone **9** (21%) as the only identifiable product. None of the expected cycloadduct, a tetrahydrothioxanthenone, was observed. As with **8**, the ^{1}H NMR spectrum of this material exhibited a low field signal (δ 3.01) for the C-5 methyl group owing to the proximity of the *peri* carbonyl group. Although the yields are modest these cycloadditions provide a new route to derivatives of 9-oxothioxanthene-3,4-dicarboxylic acid, which, previously have only been accessible by a circuitous route involving a S_NAr reaction of 4-nitrophthalimide and thiosalicylic acid.[18]

In 1968, Fravolini and co-workers reported the reaction of 3-methoxymethylenethiochroman-4-one, a masked β-keto aldehyde, with hydrazines to afford the first examples of 2,4-dihydrothiochromeno[4,3-*c*]pyrazoles.[3a]

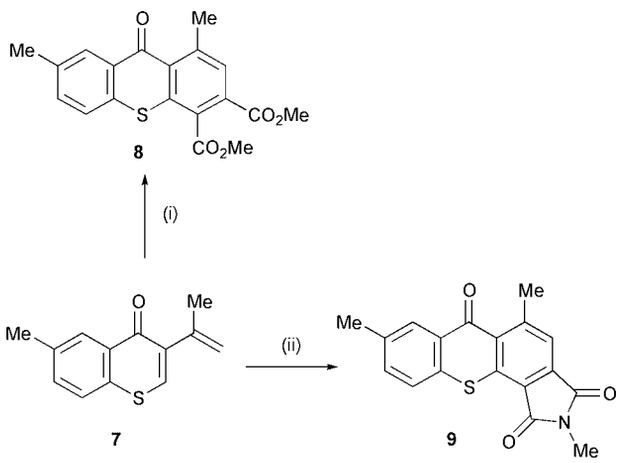
Refluxing a solution of **2** (R = Me, X = H) with hydrazine hydrate in ethanol gave the pyrazole **10** (R = Me, X = H) in excellent yield (Scheme 5). The ^{1}H NMR spectrum of **10** (R = Me, X = H) exhibits a singlet at 7.44 ppm assigned to H-3. A poorly resolved multiplet at 7.84 ppm is attributed to H-9, a value comparable to that quoted for some previously reported pyrazoles (7.80 ppm).[3a] The N–H proton appears as a very broad signal centred around 9.1 ppm. This loss of resolution may be attributed to annular prototropy, a feature common to *N*-unsubstituted pyrazoles in solution.[19] Thus in solution the 1*H*-pyrazole **10a** appears to be in equilibrium with its 2*H*-tautomer **10b**. 2,4-Dimethyl-2,4-dihydrothiochromeno[4,3-*c*]-pyrazole **12** (R = X = H) was similarly prepared from methylhydrazine but was not very stable at room temperature, affording a red semi-solid after 36 hours. The instability of some pyrazoles has been noted previously.[20] The ^{1}H NMR spectrum confirmed the exclusive formation of the 2-methyl isomer, displaying a sharp singlet at 7.14 ppm, indicative of a proton at the 3-position. The 2-Me group absorbs at 3.88 ppm, in keeping with data for similarly substituted pyrazoles.[21]

The 1-phenyl-4-methyl-1,4-dihydro- and 2,4-dimethyl-2,4-dihydro-thiochromeno[4,3-*c*]pyrazoles **11** (R = X = Me) and **12** (R = X = Me) were obtained in respectable yields when phenyl- and methyl-hydrazine were reacted with the hydroxymethylene compound **2** (R = X = Me) (Scheme 5). No isomeric pyrazoles were detected by ^{1}H NMR spectroscopy or TLC.

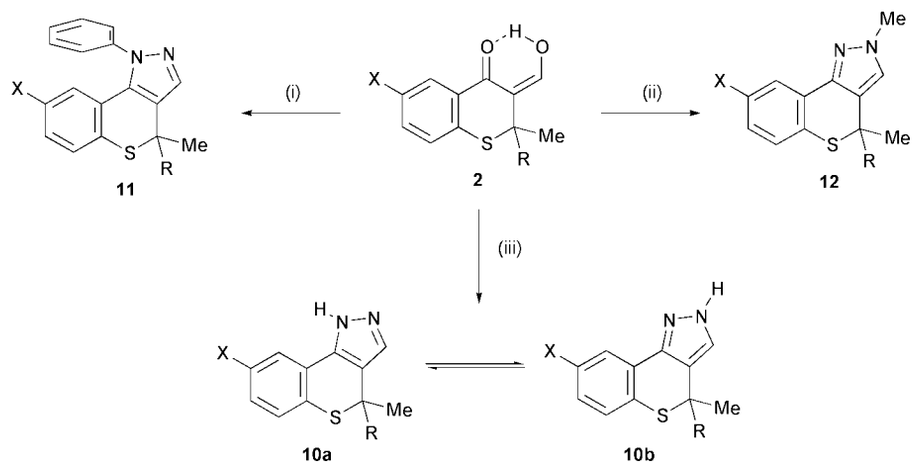
A remarkable feature in the ^{1}H NMR spectrum of the phenylpyrazole **11** (R = X = Me) is the upfield shift of H-9, which absorbs at 6.65 ppm. The corresponding proton in the methylpyrazole **12** (R = X = Me) absorbs at 7.76 ppm. It would appear that H-9 lies in the shielding zone of the 1-phenyl substituent, suggesting that the disposition of the phenyl ring is perpendicular with respect to the major plane of the molecule.

The formation of these pyrazoles may be rationalised by initial attack of the more nucleophilic nitrogen atom of the hydrazine on the hydroxymethylene appendage followed by dehydration to give an ene-hydrazine for the methyl analogue or a phenylhydrazone that may be in equilibrium with its ene-hydrazine tautomer. A 5-*exo*-*trig* ring closure of these intermediates with subsequent dehydration affords the pyrazoles.

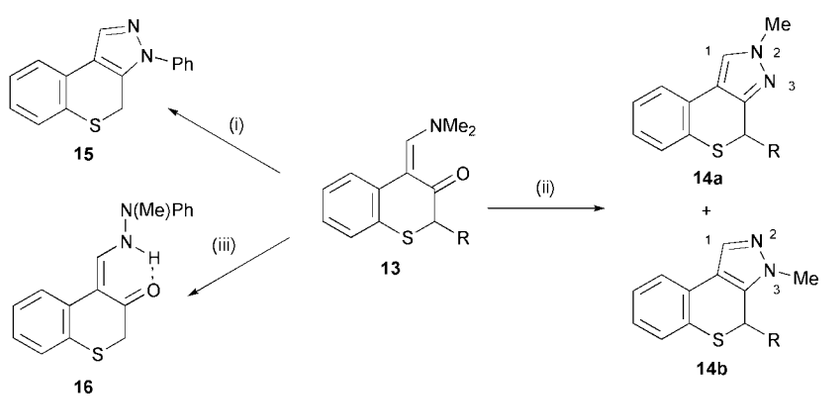
The hitherto unknown isomeric 2,4- and 3,4-dihydrothiochromeno[3,4-*c*]pyrazoles **14a**,**b** (R = H or Me) were obtained in high yield by refluxing the 4-(dimethylaminomethylene)thiochroman-3-ones **13** (R = H or Me)[22] in ethanol containing methylhydrazine (Scheme 6). After distillation, the pyrazoles were obtained as pale green oils.



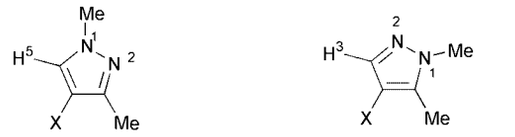
Scheme 4 *Reagents and conditions*: (i) DMAD, xylene, Δ; (ii) *N*-methylmaleimide, xylene, Δ.



Scheme 5 *Reagents and conditions*: (i) $PhNHNH_2$, EtOH, Δ; (ii) $MeNHNH_2$, EtOH, Δ; (iii) $NH_2NH_2{\cdot}H_2O$, EtOH, Δ.



Scheme 6 *Reagents and conditions*: (i) $PhNHNH_2$, EtOH, Δ; (ii) $MeNHNH_2$, EtOH, Δ; (iii) $PhN(Me)NH_2$, EtOH, Δ.



X = Me, H-5 = 7.02 ppm
X = Ph, H-5 = 7.33 ppm

X = Me, H-3 = 7.19 ppm
X = Ph, H-3 = 7.50 ppm

Fig. 2 ^{1}H NMR data for substituted *N*-methylpyrazoles.

The ^{1}H NMR spectra of these pyrazoles indicated that they had been isolated as an unequal mixture of two isomers. The spectrum of the 4-methyl analogue **14a** (R = Me) displayed doublets centred at 1.43 and 1.61 ppm and quartets at 4.07 and 4.33 ppm for the 4-methyl protons and H-4, respectively. The presence of the isomeric pyrazoles was further confirmed by N-Me signals at 3.82 and 3.87 ppm and pyrazole ring proton absorptions at 7.74 and 7.53 ppm. The isomers are presumed to have the structures **14a**,**b** (R = Me). Attempts to resolve the mixtures using centrifugal and flash chromatographic techniques failed.

NMR data are available for isomeric monocyclic *N*-methylpyrazoles and show that H-3 absorbs marginally downfield of H-5 (Fig. 2).[21,23] Comparison of the related NMR data for the thiochromenopyrazoles **14** allows a tentative assignment of the signals to the individual isomers and hence enables the predominant isomer to be identified. The reaction of methylhydrazine with **13**, both R = H and R = Me, appears to show a distinct preference (~5 : 2) for formation of the 2-methyl isomer **14a** (R = H, Me). It is likely that these major pyrazole isomers result from attack by the more nucleophilic N-Me function of the hydrazine on the aminomethylene appendage. Subsequent ring closure of the intermediates with dehydration affords the pyrazoles. The minor isomers **14b** (R = H, Me) result from a similar sequence although the initial attack now comes from the less nucleophilic nitrogen atom of the hydrazine.

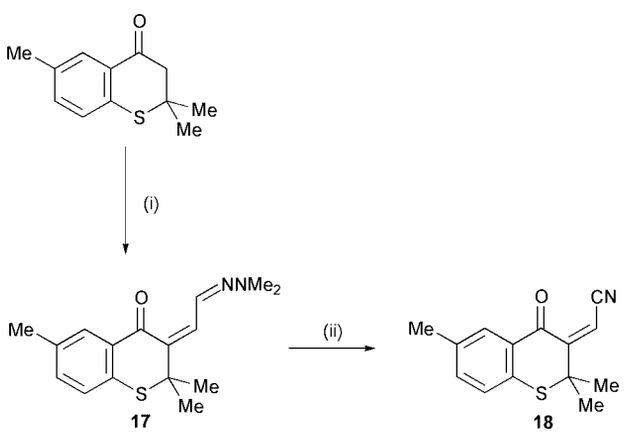
Refluxing the aminomethylene derivative **13** (R = H) with phenylhydrazine in ethanol afforded a pale yellow crystalline solid. The ^{1}H NMR spectrum showed the product to be a single isomer, since only one singlet, characteristic of a pyrazole ring proton, was observed at δ 7.96.

The potential for the formation of two isomeric pyrazoles from this reaction is significantly reduced because of the considerable difference in the nucleophilic character of the nitrogen atoms of phenylhydrazine. The isolated phenylpyrazole is presumed to have the structure **15** rationalised by attack of the more nucleophilic nitrogen on the aminomethylene function, with subsequent 5-*exo*-*trig* ring closure and dehydration.

In order to confirm the mode of addition of the phenylhydrazine to the enaminone, 1-methyl-1-phenylhydrazine was condensed with the aminomethylene derivative **13** (R = H). The hydrazine tautomer **16** was obtained exclusively according to the spectroscopic data. The ^{1}H NMR spectrum displays a singlet at 3.26 ppm assigned to the N-Me function and the C-2 methylene absorbs at 3.38 ppm, comparable with the chemical shift of the methylene function of **13** (R = H).[22] The vinylic proton appears as a poorly resolved doublet at 7.59 ppm, showing coupling to the N–H proton, which itself affords a relatively broad signal at 11.21 ppm, the low field shift indicating intramolecular hydrogen bonding to the carbonyl function. The infrared spectrum of **16** displayed an N–H stretching band at 3177 cm^{-1} and an α,β-unsaturated carbonyl stretching band at 1632 cm^{-1}. Neither the enol nor hydrazone tautomers were detected. The exclusive formation of the ene-hydrazine **16** is in agreement with the proposed 1,4-addition of the hydrazine to the aminomethylene derivative **13** (R = H). A similar process can now be rationalised for the addition of phenylhydrazine which ultimately affords only the 3-phenyl-3,4-dihydrothiochromeno[3,4-*c*]pyrazole **15**.

The use of glyoxal monohydrazones in heterocyclic synthesis has been well documented.[24] We have previously reported the condensation of glyoxal mono(*N*,*N*-dimethylhydrazone) with thiochroman-4-ones to obtain hydrazonoethylidene intermediates such as **17** which underwent a reductive cyclisation on treatment with sodium dithionite in ethanol to afford some benzothiopyrano[3,4-*c*]pyrroles.[6] We now note that the dropwise addition of aqueous HCl to a cold stirred solution of (*Z*)-3-(dimethylhydrazonoethylidene)-2,2,6-trimethylthiochroman-4-one **17** in diethyl ether gave a bright yellow crystalline solid after elution of the crude reaction product from silica.

The ^{1}H NMR spectrum of this solid displayed a sharp singlet at 5.59 ppm, integrating for one proton. This chemical shift is typical of an alkenyl proton *viz.* 3-methylene-4-oxothiochromane 1,1-dioxide.[25] The signal furthest downfield at 8.03 ppm, which appeared as a *meta*-split doublet, J = 1.7 Hz, is indicative of H-5 in thiochroman-4-ones, thereby implying that the *peri* carbonyl function is intact. This inference was confirmed by the infrared spectrum which displayed a carbonyl stretching band at 1682 cm^{-1}, typical of thiochroman-4-ones. More interestingly, a sharp band at 2224 cm^{-1} was also present, which was assigned to a nitrile function. From this evidence structure **18** was assigned to this product (Scheme 7).

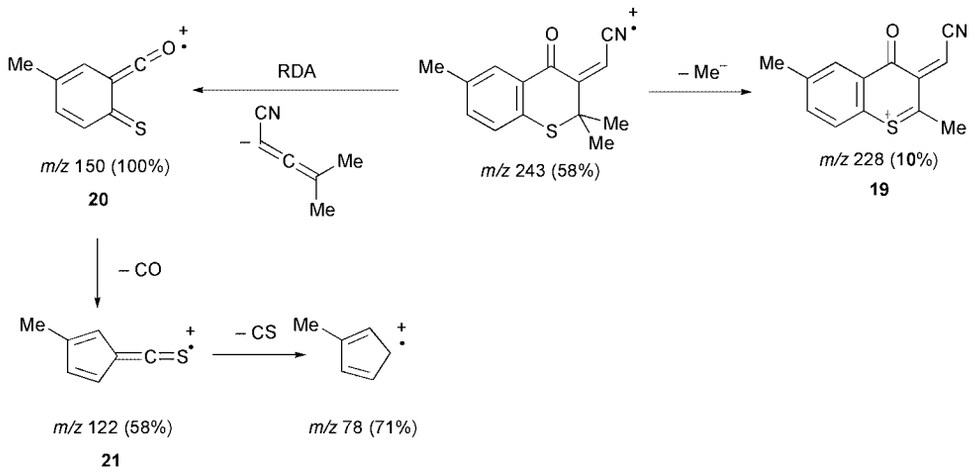


Scheme 7 *Reagents and conditions*: (i) KOtBu, $Me_2NN{=}CHCHO$, anhyd. EtOH, Δ; (ii) HCl, Et_2O, −10 °C–RT.

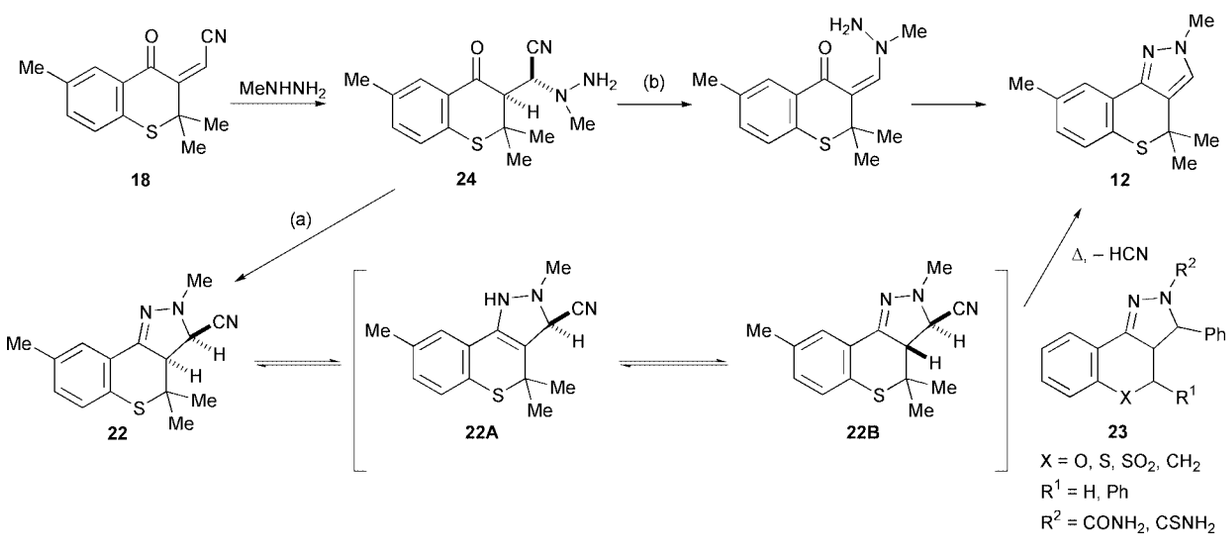
An electron impact mass spectrum of **18** showed major peaks at *m*/*z* 243 $[M]^+$ and at 228, 150, 122, 78 which are assigned in Scheme 8. The $[M - Me]^+$ ion **19** arises by loss of a 2-methyl group, a pathway which is generally prominent in the fragmentation of 2,2-dimethylchromanones.[26] Retro Diels–Alder (RDA) fragmentation of the molecular ion affords the $[RDA]^+$ ion **20** *m*/*z* 150 as the base peak. Subsequent loss of CO leads to **21** *m*/*z* 122 and loss of CS completes the sequence.

The cyanomethylene derivative **18** probably arises by protonation of the dimethylamino function followed by 1,2-elimination of dimethylammonium chloride. The facile formation of this cyanomethylene derivative in a respectable 51% yield is quite remarkable. Severin and Poehlmann have observed the formation of some related compounds but in low yields (*ca.* 10%).[27]

The reaction of chloromethylene carbonyl compounds,[28] methylthiomethylene ketones,[29] pyrrolidinomethylene ketones[16d] and α,β-unsaturated ketones[30] with substituted hydrazines has proved to be a fruitful entry to the pyrazole ring. Success has also attended the use of β-oxonitriles,[31] which ultimately afford amino-substituted pyrazoles. However, the use of β-oxovinylnitriles in pyrazole synthesis appears to have been overlooked. Two products were isolated when 3-cyanomethylene-2,2,6-trimethylthiochroman-4-one **18** was refluxed in ethanol with methylhydrazine. These were characterised as the 3-cyano-2,4,4,8-tetramethyl-2,3,3a,4-tetrahydrothiochromeno[4,3-*c*]-pyrazole **22** (50%) and 2,4,4,8-tetramethyl-2,4-dihydrothio-



Scheme 8



Scheme 9

chromeno[4,3-*c*]pyrazole **12** (R = X = Me) (21%). The structure of **22** was corroborated by the presence of a nitrile stretching band at 2245 cm^{-1} in the infrared spectrum.

In the ^1H NMR spectrum of **22**, the *geminal* methyls at C-4 are non-equivalent and absorb at 1.35 and 1.51 ppm. Such non-equivalence is typical of the C-3 unsymmetrically substituted thiochromanone system. The N-Me group absorbs at 3.03 ppm, a shift that compares favourably with reported values for 2-methylpyrazolines.[32] The 3- and 3a-protons form an AB system with doublets at 3.95 and 3.50 ppm, respectively, with a coupling constant of 13.4 Hz. Comparison of this coupling constant with the data for several substituted 2-pyrazolines[32] indicates a *cis*-orientation of the protons about the C-3–C-3a bond in **22**. The *cis-vicinal* coupling constants fall within the range 9.9–13.5 Hz and are larger than the corresponding *trans-vicinal* coupling constants (2.3–9.5 Hz). However, work reported by Tóth *et al.*[3j] describing the formation of some fused 3-phenyl-2-pyrazolines **23** from benzylidene-chroman-4-ones, -thiochroman-4-ones and -tetralones by reaction with substituted hydrazines, concluded that the *cis*- and *trans*-stereoisomers cannot always be differentiated by means of the $J_{3,3a}$ coupling constants or from the chemical shifts of the 3- and 3a-protons. Using homonuclear proton–proton nuclear Overhauser effect difference spectroscopy and 2-dimensional ^{13}C–^1H NMR correlation maps, Tóth *et al.* confirmed that the *cis*-stereoisomers were isolated exclusively for the hetero-fused dihydropyrazoles **23**. The *cis*-$J_{3,3a}$ coupling constants were in the range 11.0–11.4 Hz for all of these compounds and thus support the exclusive formation of the *cis*-H-3,H-3a stereoisomer **22** in the present work.

One feature of interest in the ^1H NMR spectrum of the second product **12** (R = X = Me) is the downfield shift of the N-Me signal to 3.94 ppm compared to that in the 2-pyrazoline **22** (3.03 ppm). We attribute this considerable shift of 0.91 ppm to the aromatic character of the pyrazole ring.

A possible mechanism that accounts for the formation of these pyrazole derivatives is outlined in Scheme 9. Initial nucleophilic attack on the cyanomethylene appendage appears to be stereospecific and affords the α-(cyanoalkyl)hydrazine **24**. From this point, two routes (a) and (b) may be considered. In route (a), a 5-*exo-trig* ring closure followed by dehydration affords **22**. The stereochemistry of this pyrazoline **22** is derived from the *syn* orientation of the hydrazino group and H-3 in **24**. In route (b), elimination of HCN by loss of the acidic C-3 proton affords an ene-hydrazine which undergoes a 5-*exo-trig* ring closure and dehydration to afford the aromatic pyrazole **12** (R = X = Me). The former route is apparently favoured since **22** is the predominant product.

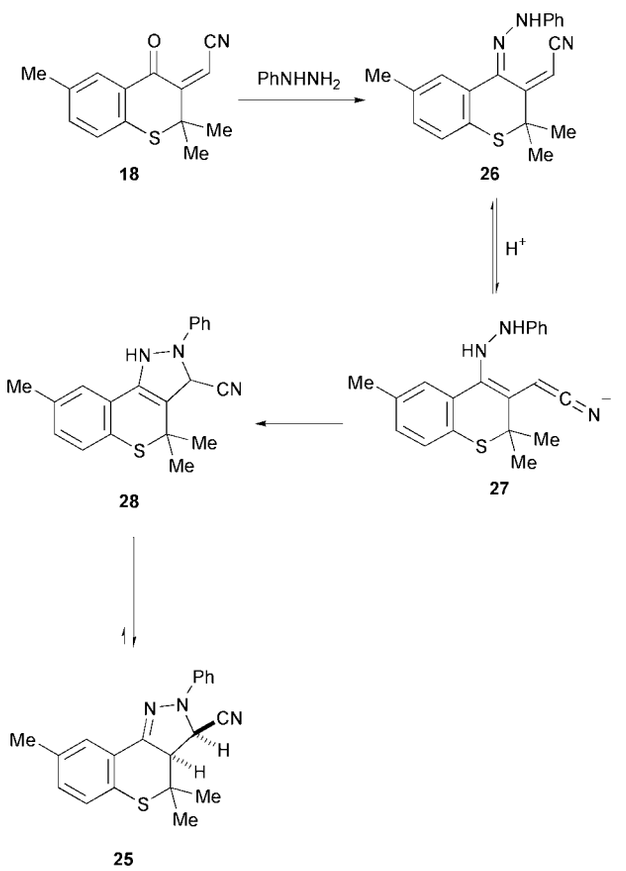
The direct conversion of **22** to **12** (R = X = Me) was accomplished in excellent yield (98%) by refluxing **22** in toluene for 40 h. It is highly improbable that under these conditions, loss of HCN would proceed *via* an E2 pathway. Also a thermal *anti*-elimination is unlikely, since reactions of this type are very rare.[33] The elimination may occur by prototropic interconversion to the isomeric *trans*-3,3a-H 2-pyrazoline **22B** *via* the 3-pyrazoline **22A**. Elimination of HCN from the *trans*-isomer **22B** can be readily achieved by an E_i mechanism because of the *syn*-orientation of the substituents. 1,4-Elimination of HCN from the intermediate 3-pyrazoline **22A** is also possible. Alternatively, N-2 may assist in the displacement of CN^- from

22, deprotonation of the resulting cation affords the pyrazole. A similar process may occur with 2-pyrazolines that have a 5-amino or 5-hydroxy substituent which can be readily eliminated.[34] At present the mechanism for this elimination remains uncertain.

Refluxing the cyanomethylene derivative **18** with phenylhydrazine in ethanol for several hours afforded 3-cyano-2-phenyl-4,4,8-trimethyl-2,3,3a,4-tetrahydrothiochromeno[4,3-*c*]-pyrazole **25** in low yield. No fully unsaturated pyrazole was isolated.

The ^{1}H NMR spectrum of **25** displayed an AB system with a coupling constant of $J_{3,3a} = 11.1$ Hz, again inferring a *cis*-orientation of the C-3–C-3a protons.[3j] However, the AB system is shifted downfield in comparison to the methyl analogue **22**, absorbing at 4.23 and 4.38 ppm. The magnitude of this shift is typical for such 2-pyrazolines and has been documented by Elguero *et al.*[32] The *peri* proton at the 9-position in **25** absorbs at 7.90 ppm which further supports the proposed structure since H-9 in the 1-phenylpyrazole **11** (R = X = Me) absorbs at 6.65 ppm as a consequence of the proximity of the phenyl ring. The nitrile stretching frequency appears at 2238 cm^{-1} in the infrared spectrum.

The formation of **25** poses an interesting mechanistic problem. In neutral or acidic media, phenylhydrazine reacts at the N-2 atom.[35] It has been suggested that the mechanism for the formation of 2-pyrazolines from β-aryl- and β-chloro-vinyl ketones and phenylhydrazine involves the initial formation of a hydrazone.[36] If this is the case with the cyanomethylene derivative **18**, the mechanism outlined in Scheme 10 may



Scheme 10

be operative. 1,2-Addition of phenylhydrazine followed by dehydration affords the hydrazone **26**. At first sight it would appear that the ensuing ring closure is a 5-*endo*-*trig* process, a disfavoured mode and in violation of Baldwin's Rules.[37] Formation of the pyrazoline is probably initiated by protonation of the hydrazone nitrogen. An electron shift affords the ene-hydrazine **27**, which contains an electron deficient nitrogen atom. The subsequent ring closure is now a favoured 5-*exo*-*trig* process and affords the 3-pyrazoline **28**, which interconverts to its imine tautomer, the 2-pyrazoline **25**. Although the stereospecificity of this tautomerism is uncertain, we only detected **25** from this reaction and it is possible that the *cis*-isomer is the thermodynamically more stable. It is pertinent to note that the 2-pyrazolines **23** isolated by Tóth *et al.*[3j] were characterised as the *cis*-isomers, suggesting that these may be thermodynamically more stable than the corresponding *trans*-isomers.

Further investigation into the addition of substituted hydrazines to α,β-unsaturated ketones is warranted, with a special emphasis placed upon their mode of addition and ring closure. From this work it is suggested that the addition of substituted hydrazines to α,β-unsaturated ketones depends upon the nucleophilicity of the hydrazine, the more nucleophilic methylhydrazine favouring 1,4-addition, whereas the less nucleophilic phenylhydrazine favours a 1,2-process.

The addition of hydrazines to the β-ketoaldehydes **2** is apparently straightforward. The more nucleophilic nitrogen atom of the hydrazine attacks the more electrophilic vinylic carbon atom and subsequent ring closure affords the predicted pyrazoles as single isomers. When there is a less marked difference in nucleophilicity between the two nitrogen atoms of the hydrazine, as in $MeNHNH_2$, isomeric mixtures may still result, since steric factors may also play a part. Thus, N-1 of methylhydrazine is more nucleophilic but is also more sterically hindered than N-2. These features are exemplified by the formation of the pyrazoles **14a** and **14b** from **13** (R = Me).

Experimental

Melting points were determined in capillary tubes and are uncorrected. Distillations were performed using a Kugelrohr (Büchi GKR-50 Glass Tube Oven) and all boiling points quoted relate to the oven temperature at which the distillation commenced. Fourier transform infrared spectra were recorded on a Mattson Polaris spectrophotometer. ^{1}H and ^{13}C NMR spectra were recorded on a Bruker WM 250 MHz instrument for solutions in $CDCl_3$, *J* values are given in Hz. Flash chromatographic separations were performed on Crossfields Sorbsil C60 silica (M.P.D. 60 Å, 40–60 m, activated) according to the general procedure.[38]

General method for the preparation of 3-hydroxymethylene-thiochroman-4-ones 2

Sodium methoxide [prepared from sodium (0.3 mol) and methanol (150 cm^3)] was slurried in dry toluene (150 cm^3) and cooled to 0 °C. Ethyl formate (0.3 mol) was added in a single portion and the mixture was vigorously stirred as a solution of the thiochroman-4-one (0.15 mol) in dry benzene (100 cm^3) was added dropwise over a period of 15 min.

In most cases the reaction mixture became dark yellow or brown after the addition was complete and all the sodium methoxide dissolved. The resulting mixture was allowed to stir overnight or until it had become thick and gelatinous.

After this period, water was added with vigorous stirring and the toluene layer was extracted with water (3 × 75 cm^3). The aqueous extracts were combined and washed with toluene (2 × 75 cm^3). The aqueous phase was then cautiously acidified with concentrated hydrochloric acid. The crude hydroxymethylene derivative was extracted into ethyl acetate (3 × 50 cm^3), whereupon removal of the dried (Na_2SO_4) solvent afforded the hydroxymethylene derivative which was further purified by bulb-to-bulb distillation.

3-Hydroxymethylene-2,2-dimethylthiochroman-4-one 2 (R = Me, X = H). (65%) As a yellow oil, bp 120 °C at 4 × 10^{-2} mmHg; δ_H 1.63 (6H, s, 2-Me), 7.20–7.41 (3H, m, 6-H, 7-H, 8-H), 8.04 (1H, dd, *J* 8.1, 1.5, 5-H), 8.35 (1H, d, *J* 6.8,

alkenyl-H), 15.80 (1H, d, *J* 6.8, OH) (Found: C, 65.3; H, 5.5; S, 14.5. $C_{12}H_{12}O_2S$ requires C, 65.4; H, 5.5; S, 14.6%).

3-Hydroxymethylene-2-methylthiochroman-4-one 2 (R = X = H). (91%) As a bright yellow oil, bp 95 °C at 7×10^{-2} mmHg; δ_H 1.48 (3H, d, *J* 7.2, 2-Me), 3.86 (1H, q, *J* 7.1, 2-H), 7.20–7.41 (3H, m, 6-H, 7-H, 8-H), 8.00 (1H, dd, *J* 7.2, 1.5, 5-H), 8.58 (1H, br s, alkenyl-H), 14.79 (1H, br s, OH) (Found: C, 63.8; H, 4.8; S, 15.3. $C_{11}H_{10}O_2S$ requires C, 64.0; H, 4.9; S, 15.5%).

3-Hydroxymethylene-2,2,6-trimethylthiochroman-4-one 2 (R = X = Me). (49%) As a bright yellow oil, bp 130 °C at 3×10^{-2} mmHg; δ_H 1.60 (6H, s, 2-Me), 2.35 (3H, s, 6-Me), 7.12–7.22 (2H, m, 7-H, 8-H), 7.84 (1H, d, *J* 1.1, 5-H), 8.30 (1H, d, *J* 6.7, alkenyl-H), 15.82 (1H, d, *J* 6.7, OH) (Found: C, 66.6; H, 5.8; S, 13.4. $C_{13}H_{14}O_2S$ requires C, 66.6; H, 6.0; S, 13.7%).

6-Chloro-3-hydroxymethylene-2-methylthiochroman-4-one 2 (X = Cl, R = H) and 6-chloro-3-[1-(6-chloro-2-methyl-4-oxothiochroman-3-ylethyl]-4*H*-thiochromen-4-one 3. Attempts to prepare 6-chloro-3-hydroxymethylene-2-methylthiochroman-4-one **2** (X = Cl, R = H) by the previously described procedure gave two products, which were separated on elution from silica with 20% ethyl acetate in *n*-hexane. Fraction 1 (**2**, R = H, X = Cl) (43%) as a pale yellow oil, bp 120 °C at 7×10^{-2} mmHg; δ_H 1.45 (3H, d, *J* 7.1, 2-Me), 3.86 (1H, q, *J* 7.1, 2-H), 7.22–7.35 (2H, m, Ar-H), 7.95 (1H, d, *J* 1.6, 5-H), 8.60 (1H, br s, alkenyl-H), 14.80 (1H, br s, OH) (Found: C, 54.8; H, 3.5; Cl, 14.6; S, 13.1. $C_{11}H_9ClO_2S$ requires C, 54.9; H, 3.8; Cl, 14.7; S, 13.3%).

Fraction 2, the more polar 6-chloro-3-[1-(6-chloro-2-methyl-4-oxothiochroman-3-yl)ethyl]-4*H*-thiochromen-4-one **3**, (22%) as colourless crystals from ethyl acetate and *n*-hexane, mp 180.0–181.5 °C; ν_{max} (Nujol) 1675, 1610 cm^{-1}; δ_H 1.22 (3H, d, *J* 7.8, Me), 1.42 (3H, d, *J* 7.6, Me), 3.00–3.10 (1H, m, H), 3.34 (1H, dd, *J* 10.1, 3.3, H), 3.40–3.46 (1H, m, H), 7.13 (1H, d, *J* 8.3, Ar-H), 7.34 (1H, dd, *J* 8.3, 2.1, Ar-H), 7.54–7.59 (2H, m, Ar-H), 7.87 (1H, s, H), 8.01 (1H, d, *J* 2.3, Ar-H), 8.52 (1H, dd, *J* 1.1, 1.0, Ar-H) (Found: C, 57.9; H, 3.6; Cl, 16.4; S, 14.6. $C_{21}H_{16}Cl_2O_2S_2$ requires C, 57.9; H, 3.7; Cl, 16.3; S, 14.7%).

Rearrangement of 3-hydroxymethylene-2,2,6-trimethylthiochroman-4-one 2 (R = X = Me)

A solution of 3-hydroxymethylene-2,2,6-trimethylthiochroman-4-one **2** (R = X = Me) (13 mmol) in methanesulfonic acid (40 cm^3, 98%) was maintained at room temperature for 60 hours. The solution was poured into ice–water (300 cm^3) and extracted with EtOAc (3 × 50 cm^3). The combined organic extracts were washed with water (2 × 50 cm^3), NaOH (2 M, 2 × 50 cm^3) and finally with water (100 cm^3). Removal of the dried solvent gave a pale brown solid which was eluted from silica with 10% EtOAc in hexane to give 3-isopropenyl-6-methylthiochromen-4-one **7** (56%) as colourless plates after recrystallisation from hexane and EtOAc, mp 71.0–73.0 °C; ν_{max} (KBr) 1618, 1595 cm^{-1}; δ_H 2.13 (3H, m, C(*Me*)=CH_2), 2.48 (3H, s, 6-Me), 5.16 (1H, m, C(Me)=CH_2), 5.21 (1H, m, C(Me)=CH_2), 7.41 (1H, dd, *J* 8.3, 2.0, 7-H), 7.48 (1H, d, *J* 8.3, 8-H), 7.76 (1H, s, 2-H), 8.39 (1H, d, *J* 2.0, 5-H) (Found: C, 72.1; H, 5.65; S, 14.7. $C_{13}H_{12}OS$ requires C, 72.2; H, 5.6; S, 14.8%).

General method for the preparation of thioxanthenones 8 and 9

A solution of 3-isopropenyl-6-methylthiochromen-4-one **7** (2.75 mmol) and the dienophile (2.75 mmol) in xylene (15 cm^3) was refluxed until TLC examination of the reaction mixture indicated that no **7** remained. Removal of the xylene gave a dark brown gum which was eluted from silica with 40% EtOAc in hexane to afford the thioxanthenones which were further purified by recrystallisation.

Dimethyl 1,7-dimethyl-9-oxo-9*H*-thioxanthene-3,4-dicarboxylate 8. (34%) As yellow microcrystals from EtOAc and hexane, mp 166.0–168.0 °C; δ_H 2.47 (3H, s, 7-Me), 2.91 (3H, s, 1-Me), 3.95 (3H, s, CO_2Me), 4.04 (3H, s, CO_2Me), 7.43 (2H, m, Ar-H), 7.77 (1H, d, *J* 1.0, Ar-H), 8.19 (1H, s, 8-H); δ_C 21.1, 24.7, 53.0, 53.2, 125.5, 129.2, 129.6, 130.1, 130.3, 131.3, 132.1, 133.8, 134.9, 137.0, 145.3, 165.3, 165.5, 167.3, 182.7 (Found: M^+, 356.0716; C, 64.0; H, 4.4; S, 8.9. $C_{19}H_{16}O_5S$ requires M^+, 356.0718; C, 64.0; H, 4.5; S, 9.0%).

2,5,8-Trimethyl-1,2,3,6-tetrahydrothiochromeno[2,3-*e*]isoindole-1,3,6-trione 9. (21%) As fine yellow needles from EtOAc and hexane, mp 267.5–269.0 °C; δ_H 2.49 (3H, s, 8-Me), 3.01 (3H, s, 5-Me), 3.22 (3H, s, 2-Me), 7.48 (2H, m, Ar-H), 7.66 (1H, d, *J* 0.9, Ar-H), 8.26 (1H, s, 7-H) (Found: M^+, 323.0612; C, 66.8; H, 4.1; N, 4.1, S, 9.9. $C_{18}H_{13}NO_3S$ requires M^+, 323.0616; C, 66.85; H, 4.1; N, 4.3, S, 9.9%).

(*Z*)-3-Cyanomethylene-2,2,6-trimethylthiochroman-4-one 18

Hydrochloric acid (1:1 aq., 15 cm^3) was added dropwise over a period of 30 min to a stirred solution of (*Z*)-3-(dimethylhydrazonoethylidene)-2,2,6-trimethylthiochroman-4-one **17**[6] (5 mmol) in diethyl ether (40 cm^3) at −10 °C. The resulting dark brown solution was allowed to warm to room temperature over 30 min and was then diluted with water (100 cm^3) and extracted with ethyl acetate (3 × 50 cm^3). Removal of the dried (Na_2SO_4) solvent afforded a dark brown oil which was eluted from silica with 20% ethyl acetate in *n*-hexane to afford the title compound (51%) as bright yellow needles from *n*-hexane and ethyl acetate, mp 134.0–135.5 °C; ν_{max} (Nujol) 2224, 1682 cm^{-1}; δ_H 1.63 (6H, s, 2-Me), 2.37 (3H, s, 6-Me), 5.59 (1H, s, alkenyl-H), 7.12 (1H, d, *J* 8.2, 8-H), 7.30 (1H, dd, *J* 8.2, 1.7, 7-H), 8.03 (1H, d, *J* 1.7, 5-H) (Found: C, 68.8; H, 5.4; N, 5.8; S, 13.3. $C_{14}H_{13}NOS$ requires C, 69.1; H, 5.4; N, 5.75; S, 13.2%).

General method for the preparation of thiochromenopyrazoles

A mixture of either the 3-hydroxymethylenethiochroman-4-one **2** or the 4-(dimethylaminomethylene)thiochroman-3-one **13** (8 mmol) and the appropriate hydrazine (10 mmol) in ethanol (25 cm^3) was refluxed until TLC examination of the reaction mixture indicated that the reaction was complete (*ca.* 1 h). The solvent was removed and the residue diluted with water (50 cm^3) and extracted into ethyl acetate (3 × 30 cm^3). The combined organic extracts were thoroughly washed with water (3 × 75 cm^3), dried (Na_2SO_4) and evaporated to afford the crude pyrazoles, which were further purified by recrystallisation or distillation.

4,4-Dimethyl-1,4-dihydrothiochromeno[4,3-*c*]pyrazole 10 (R = Me, X = H). (75%) From hydrazine hydrate and **2** (X = H, R = Me) as pale yellow needles from light petroleum (bp 40–60 °C) and ethyl acetate, mp 133.0–134.5 °C; δ_H 1.66 (6H, s, 4-Me), 7.15–7.25 (2H, m, Ar-H), 7.38 (1H, m, Ar-H), 7.44 (1H, s, 3-H), 7.84 (1H, br m, 9-H), 9.14 (1H, br s, NH) (Found: C, 66.7; H, 5.6; N, 13.1; S, 14.9. $C_{12}H_{12}N_2S$ requires C, 66.6; H, 5.6; N, 13.0; S, 14.8%).

2,4,4,8-Tetramethyl-2,4-dihydrothiochromeno[4,3-*c*]pyrazole 12 (R = X = Me). (84%) From methylhydrazine and **2** (X = R = Me) as colourless crystals from light petroleum (bp 40–60 °C), mp 104.0–105.0 °C; δ_H 1.62 (6H, s, 4-Me), 2.35 (3H, s, 8-Me), 3.94 (3H, s, 2-Me), 7.01 (1H, dd, *J* 8.0, 1.5, 7-H), 7.18 (1H, s, 3-H), 7.22 (1H, d, *J* 8.0, 6-H), 7.76 (1H, d, *J* 1.5, 9-H) (Found: C, 68.8; H, 6.7; N, 11.5; S, 13.1. $C_{14}H_{16}N_2S$ requires C, 68.8; H, 6.6; N, 11.5; S, 13.1%).

4,4,8-Trimethyl-1-phenyl-1,4-dihydrothiochromeno[4,3-*c*]pyrazole 11 (R = X = Me). (81%) From phenylhydrazine and **2** (X = R = Me) as colourless crystals from light petroleum (bp

40–60 °C) and ethyl acetate, mp 141.0–143.5 °C; δ_H 1.65 (6H, s, 4-Me), 2.04 (3H, s, 8-Me), 6.65 (1H, d, *J* 1.2, 9-H), 6.95 (1H, dd, *J* 8.0, 1.2, 7-H), 7.32 (1H, d, *J* 8.0, 6-H), 7.39–7.47 (5H, m, 1-Ph), 7.57 (1H, s, 3-H) (Found: C, 74.5; H, 5.9; N, 9.3; S, 10.6. $C_{19}H_{18}N_2S$ requires C, 74.5; H, 5.9; N, 9.2; S, 10.6%).

2,4-Dimethyl-2,4-dihydrothiochromeno[4,3-*c*]pyrazole 12 (R = X = H). (74%) From methylhydrazine and **2** (X = R = H) as pale yellow oil, bp 160 °C at 4×10^{-2} mmHg, which on standing in air at room temperature gradually decomposed to a dark red semi-solid; δ_H 1.54 (3H, d, *J* 6.8, 4-Me), 3.88 (3H, s, 2-Me), 4.35 (1H, q, *J* 6.8, 4-H), 7.14 (1H, s, 3-H), 7.19–7.32 (3H, m, 6-H, 7-H, 8-H), 7.88 (1H, dd, *J* 8.3, 2.5, 9-H) (Found: C, 66.5; H, 5.6; N, 13.2; S, 14.8. $C_{12}H_{12}N_2S$ requires C, 66.6; H, 5.6; N, 13.0; S, 14.8%).

2-Methyl-2,4-dihydrothiochromeno[3,4-*c*]pyrazole 14a (R = H) and the 3-methyl isomer 14b (R = H). (Mixture, 84%) from methylhydrazine and **13** (R = H), as a pale yellow oil after bulb-to-bulb distillation, bp 160–175 °C at 6×10^{-2} mmHg; δ_H† 3.81 (3H, s, N-Me), 3.87 (3H, s, N-Me), 3.96 (2H, s, 4-H), 3.97 (2H, s, 4-H), 7.03–7.18 (4H, m, Ar-H), 7.28–7.34 (3H, m, Ar-H), 7.36–7.40 (1H, m, Ar-H), 7.44 (1H, s, 1-H), 7.61 (1H, s, 1-H) (Found: C, 65.2; H, 5.0; N, 13.9; S, 16.0. $C_{11}H_{10}N_2S$ requires C, 65.3; H, 5.0; N, 13.9; S, 15.9%).

2,4-Dimethyl-2,4-dihydrothiochromeno[3,4-*c*]pyrazole 14a (R = Me) and the 3,4-dimethyl isomer 14b (R = Me). (Mixture, 87%) from methylhydrazine and **13** (R = Me), as a pale green oil after bulb-to-bulb distillation, bp 153–159 °C at 5×10^{-2} mmHg; δ_H† 1.43 (3H, d, *J* 7.2, 4-Me), 1.61 (3H, d, *J* 7.2, 4-Me), 3.82 (3H, s, N-Me), 3.87 (3H, s, N-Me), 4.07 (1H, q, *J* 7.2, 4-H), 4.33 (1H, q, *J* 7.2, 4-H), 7.06–7.17 (4H, m, Ar-H), 7.31–7.37 (3H, m, Ar-H), 7.48 (1H, dd, *J* 7.4 ,1.6, 9-H), 7.53 (1H, s, 1-H), 7.74 (1H, s, 1-H) (Found: C, 66.6; H, 5.6; N, 12.8; S, 14.7. $C_{12}H_{12}N_2S$ requires C, 66.6; H, 5.6; N, 13.0; S, 14.8%).

3-Phenyl-3,4-dihydrothiochromeno[3,4-*c*]pyrazole 15. (87%) From phenylhydrazine and **13** (R = H), as pale yellow plates from ethanol, mp 131.0–132.0 °C; δ_H 4.09 (2H, s, 4-H), 7.11–7.24 (2H, m, Ar-H), 7.34–7.54 (7H, m, Ar-H), 7.96 (1H, s, 1-H) (Found: C, 72.5; H, 4.6; N, 10.8; S, 12.2. $C_{16}H_{12}N_2S$ requires C, 72.7; H, 4.6; N, 10.6; S, 12.1%).

Preparation of 4-(1-methyl-1-phenylhydrazinomethylene)thiochroman-3-one 16

A solution of 4-(dimethylaminomethylene)thiochroman-3-one **13** (R = H) (3.2 mmol) and 1-methyl-1-phenylhydrazine (3.2 mmol) in ethanol (25 cm³) was boiled under reflux for 1.5 h. On cooling, a pale yellow solid gradually precipitated from the reaction mixture. The solid was collected by vacuum filtration and washed with a little ice cold ethanol to afford the title compound (91%) as yellow needles from ethanol, mp 154.5–155.5 °C; ν_{max} (Nujol) 1632, 3177 cm^{-1}; δ_H 3.26 (3H, s, N-Me), 3.38 (2H, s, 2-H), 6.92–7.38 (9H, m, Ar-H), 7.59 (1H, br d, alkenyl-H), 11.21 (1H, br s, N–H) (Found: C, 68.9; H, 5.5; N, 9.6; S, 11.0. $C_{17}H_{16}N_2OS$ requires C, 68.9; H, 5.5; N, 9.5; S, 10.8%).

Preparation of *cis*-3-cyano-2,4,4,8-tetramethyl-2,3,3a,4-tetrahydrothiochromeno[4,3-*c*]pyrazole 22

A solution of (*Z*)-3-cyanomethylene-2,2,6-trimethylthiochroman-4-one **18** (1.6 mmol) and methylhydrazine (2.0 mmol) were refluxed in ethanol (15 cm³) for 1 h. On cooling, the ethanol was removed and the resulting pale yellow semi-solid was eluted from silica with 20% ethyl acetate in *n*-hexane to afford two fractions. Fraction 1, the less polar title compound **22** (50%) as colourless crystals from light petroleum (bp 40–60 °C), mp 182.0–183.0 °C; ν_{max} (Nujol) 2245 cm^{-1}; δ_H 1.35 (3H, s, 4-Me), 1.51 (3H, s, 4-Me), 2.30 (3H, s, 8-Me), 3.03 (3H, s, 2-NMe), 3.50 (1H, d, *J* 13.4, 3a-H), 3.95 (1H, d, *J* 13.4, 3-H), 7.05–7.06 (2H, m, Ar-H), 7.78 (1H, s, 9-H) (Found: C, 66.4; H, 6.4; N, 15.8; S, 11.8. $C_{15}H_{17}N_3S$ requires C, 66.4; H, 6.3; N, 15.5; S, 11.8%).

Fraction 2, 2,4,4,8-tetramethyl-2,4-dihydrothiochromeno-[4,3-*c*]pyrazole **12** (R = X = Me) (21%) identical in all aspects to that prepared previously.

Thermolysis of *cis*-3-cyano-2,4,4,8-tetramethyl-2,3,3a,4-tetrahydrothiochromeno[4,3-*c*]pyrazole 22

A solution of *cis*-3-cyano-2,4,4,8-tetramethyl-2,3,3a,4-tetrahydrothiochromeno[4,3-*c*]pyrazole **22** (2 mmol) in dry toluene (10 cm³) was heated under reflux until TLC examination of the reaction mixture indicated complete conversion of reactant to product (40 h). Evaporation of the toluene gave 2,4,4,8-tetramethyl-2,4-dihydrothiochromeno[4,3-*c*]pyrazole **12** (R = X = Me) (98%) identical in all aspects to that prepared previously.

Preparation of *cis*-3-cyano-4,4,8-trimethyl-2-phenyl-2,3,3a,4-tetrahydrothiochromeno[4,3-*c*]pyrazole 25

A solution of (*Z*)-3-cyanomethylene-2,2,6-trimethylthiochroman-4-one **18** (3.0 mmol) and phenylhydrazine (4.0 mmol) were refluxed in ethanol (30 cm³) for 2.5 h. On cooling, the ethanol was removed and the resulting red semi-solid was taken up in ethyl acetate (100 cm³) and thoroughly washed with water (4×50 cm³). Removal of the dried (Na_2SO_4) solvent afforded a multi-component (TLC) dark red oil which was eluted from silica with 25% ethyl acetate in *n*-hexane to afford the title pyrazole **22** (63%) as colourless needles from light petroleum (bp 40–60 °C), mp 136.0–137.5 °C; ν_{max} (Nujol) 2238 cm^{-1}; δ_H 1.29 (3H, s, 4-Me), 1.57 (3H, s, 4-Me), 2.35 (3H, s, 8-Me), 4.23 (1H, d, *J* 11.1, 3a-H), 4.38 (1H, d, *J* 11.1, 3-H), 7.05–7.08 (3H, m, Ar-H), 7.32–7.42 (4H, m, Ar-H), 7.90 (1H, s, 9-H) (Found: C, 72.2; H, 5.7; N, 12.8; S, 9.8. $C_{20}H_{19}N_3S$ requires C, 72.1; H, 5.8; N, 12.6; S, 9.6%).

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