2-Trifluoromethyl-4*H*-thiochromen-4-one and 2-trifluoromethyl-4*H*-thiochromene-4-thione: synthesis and reactivities

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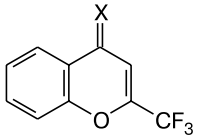
2-Trifluoromethyl-4*H*-thiochromene-4-thione obtained from 2-trifluoromethyl-4*H*-thiochromen-4-one and P_2S_5 reacts with aromatic amines, hydrazine hydrate, phenylhydrazine, and hydroxylamine at the C(4) atom of the chromene ring to give the corresponding anils, azine, hydrazones, and oxime of thiochromone. 2-Trifluoromethyl-4*H*-thiochromen-4-one is oxidized by hydrogen peroxide in AcOH into 4-oxo-2-trifluoromethyl-4*H*-thiochromene 1,1-dioxide and reduced by $NaBH_4$ to 2-trifluoromethyl-4*H*-thiochromen-4-ol or *cis*-2-(trifluoromethyl)thiochroman-4-ol. When treated with hydrazine hydrate, thiochromen-4-one gives 3(5)-(2-mercaptophenyl)-5(3)-trifluoromethylpyrazole.

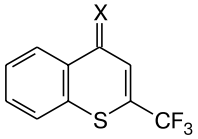
Key words: 2-trifluoromethyl-4*H*-thiochromen-4-one, oxidation, reduction, 2-trifluoromethyl-4*H*-thiochromene-4-thione; anils, hydrazones, azine, and oxime of thiochromone.

Chromones (4*H*-chromen-4-ones) belong to an important class of oxygen-containing heterocycles; many of their derivatives exhibit various kinds of biological activity and serve as the starting materials for the synthesis of novel heterocyclic systems.[1,2] Chromones substantially differ in reactivity from less accessible (and, accordingly, less well studied) sulfur analogs: 4*H*-chromene-4-thiones (chromenethiones), 4*H*-thiochromen-4-ones (thiochromones), and 4*H*-thiochromene-4-thiones (dithiochromones). For instance, nucleophiles react with chromones mainly at the C(2) atom, regardless of the presence and nature of the substituent at this atom (1,4-addition with possible opening of the pyrone ring),[2—4] while their reactions with chromenethiones and thiochromones predominantly involve the C(4) atom (1,2-addition).[5—8] The presence of an R^F group in position 2 of chromones makes them more reactive than their nonfluorinated analogs and facilitates reactions with various nucleophilic reagents at the C(2) atom (see Ref. 2). For this reason, it was of interest to find out how the reactivity of 2-trifluoromethylchromone (**1**) will change upon sequential replacement of the oxygen atoms in this compound by sulfur atoms.

Recently,[9] we have described the synthesis and most important chemical properties of 2-trifluoromethyl-4*H*-chromene-4-thione (**2**); unlike chromone **1**, this compound (despite the presence of the electron-withdrawing CF_3 group in position 2) reacts with aniline, phenylhydrazine, and hydroxylamine at the C(4) atom, which allows regiocontrolled synthesis of the corresponding pyrazoles and isoxazoles. In the present work, we obtained 2-trifluoromethyl-4*H*-thiochromen-4-one (**3**) and 2-trifluoromethyl-4*H*-thiochromene-4-thione (**4**) and studied some of their spectroscopic and chemical properties, including reactions with a number of N-nucleophiles.



1, **2**



3, **4**

X = O (**1**, **3**), S (**2**, **4**)

Literature data on the chemical properties of 4*H*-thiochromen-4-ones that have a polyhaloalkyl group at the C(2) atom are lacking. However, it is known that thiochromones and thioflavones react with P_2S_5 to give 4*H*-thiochromene-4-thiones,[10—12] are oxidized at the sulfur atom into S-oxides and S,S-dioxides,[13—17] are reduced to 4*H*-thiochromenes and 4*H*-thiochromen-4-ols,[16,17] are alkylated to form thiochromylium salts,[18] and are halogenated and chloromethylated at position 3 (see Refs 19—22). In addition, reactions of thioflavone and 2-methylthiochromone with compounds containing an active methylene (malononitrile[23] and hippuric acid[24]) or methyl group (2-methyl-4,6-diphenylpyrilium and 2-methyl-4,6-diphenylthiopyrilium perchlorates[25]) are known to occur at the carbonyl C atom. Analogously

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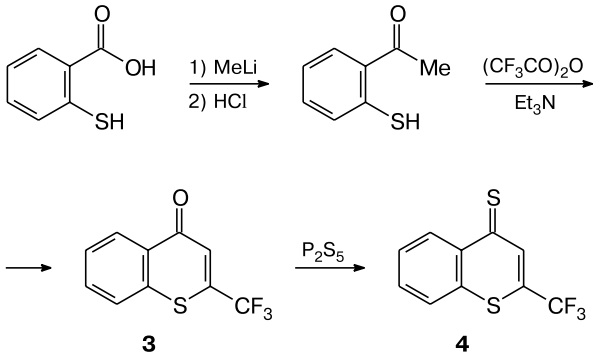
(*i.e.*, according to the 1,2-addition mechanism), 2,6-dimethylthiochromone reacts with dimethyllithium cuprate[26] and 2-trifluoromethylthiochromone reacts with trimethyl(trifluoromethyl)silane.[27] As far as we know, the nucleophilic attack of thiochromones on the C(2) atom (1,4-addition) has been found only in their reactions with the complex AlkCu—BF_3, yielding thiochromanones.[26]

Results and Discussion

2-Trifluoromethyl-4*H*-thiochromen-4-one (**3**) was first obtained[28] by the reaction of 4,4,4-trifluorobut-2-ynoic acid with benzenethiol in the presence of KOH followed by cyclization of phenylthioacrylic acid under the action of PCl_5 and $AlCl_3$ in benzene. We developed a simpler and more convenient route to 2-CF_3-thiochromone **3** (see preliminary communication[29]) by treating 2-mercaptoacetophenone (synthesized from thiosalicylic acid and methyllithium[30]) with trifluoroacetic anhydride in the presence of triethylamine in THF. The target thiochromone **3** was obtained in 57% yield; when refluxed with P_2S_5 in toluene for 1 h, it afforded earlier unknown 2-CF_3-dithiochromone **4** in 66% yield (Scheme 1).

Scheme 1



3 **4**

The ^1H and ^{19}F NMR spectra of compounds **3** and **4** are given in Table 1. For comparison, the spectroscopic data for known[9] chromone **1** and chromenethione **2** are also presented. On replacement of either O atom in chromone **1** by a sulfur atom (**1** → **2** or **1** → **3**), the signals for the H(3) and H(5) protons are substantially shifted downfield (by 0.6—0.7 and 0.3 ppm, respectively). In compound **4**, because of the total deshielding effect of two S atoms, the downfield shifts of these signals are already 1.42 and 0.67, while the signals for the H(6) and H(8) protons are shifted downfield only slightly (by 0.11 ppm). Replacement of the O(1) atom by an S atom decreases the *ortho*-constants $J_{6,7}$ and $J_{7,8}$ but increases the *meta*-constant $J_{6,8}$ and the constant of the spin-spin coupling between the H(3) proton and the CF_3 group ($^4J_{H,F}$ = 0.8—0.9 Hz). In addition, this replacement substantially affects the chemical shift of the CF_3 group (δ ~ –72 for **1** and **2** and δ ~ –65 for **3** and **4**).

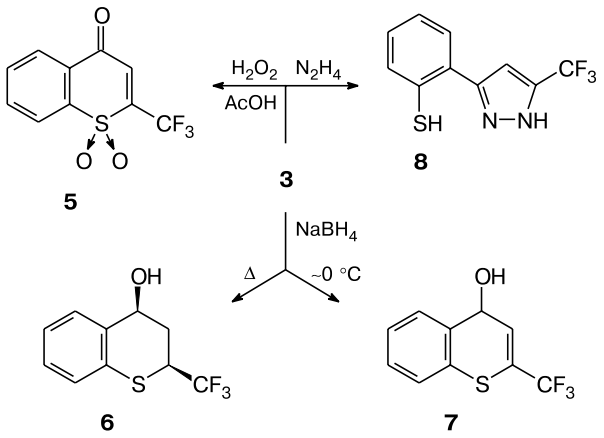
We found that thiochromone **3** is oxidized on heating with H_2O_2 in AcOH to give sulfone **5** in 42% yield; when refluxed with excess $NaBH_4$ in propan-2-ol, thiochromone **3** is reduced to *cis*-2-(trifluoromethyl)thiochroman-4-ol (**6**) in 53% yield. The *cis*-structure of thiochromanol **6** is evident from the coupling constants. For instance, in the ^1H NMR spectrum, the axial H(3a) proton manifests itself at δ 1.90 as a doublet of triplets with the geminal constant $^2J_{H(3a),H(3e)}$ = 12.8 Hz and the vicinal constants $^3J_{H(3a),H(2a)} \approx {}^3J_{H(3a),H(4a)} \approx 10.6$ Hz, which indicate the axial and pseudoaxial arrangement of the H(2) and H(4) atoms (see Ref. 31). Therefore, molecules of thiochromanol **6** in $CDCl_3$ are in the half-chair conformation with *cis*-equatorial and pseudoequatorial arrangements of the substituents. Note that reduction of flavones and chromones with $NaBH_4/NiCl_2$ in methanol also yields *cis*-flavan-4-ols and *cis*-chroman-4-ols.[32] The formation of *cis*-products is due to the fact that the hydrogenation of the enone fragment proceeds on one side because of steric hindrances. Reduction of thiochromone **3** under milder conditions (~0 °C) with a smaller excess of $NaBH_4$ can be stopped at the step of 2-trifluoromethyl-4*H*-thiochromen-4-ol (**7**); its formation suggests that the C(4) atom in compound **3** is more reactive than the C(2) atom (Scheme 2).

Table 1. ^1H and ^{19}F NMR spectra ($CDCl_3$) of compounds **1**—**4**

Compound	^1H NMR											^{19}F NMR
	δ					*J*/Hz						δ_{CF_3} ($J_{3,F}$)
	H(3)	H(5)	H(6)	H(7)	H(8)	$J_{5,6}$	$J_{5,7}$	$J_{5,8}$	$J_{6,7}$	$J_{6,8}$	$J_{7,8}$	
1	6.74	8.21	7.49	7.77	7.56	8.0	1.7	0.4	7.2	1.0	8.6	–72.2
2	7.44	8.48	7.46	7.78	7.53	8.2	1.7	0.4	7.1	1.1	8.6	–71.5
3	7.33	8.52	7.62	7.71	7.68	8.1	1.4	0.7	6.5	1.9	8.2	–65.2 (0.8)
4	8.16	8.88	7.60	7.71	7.67	8.3	1.4	0.5	6.6	1.8	8.2	–64.3 (0.9)

Note. Me_4Si (^1H) and $CFCl_3$ (^{19}F) were used as the internal standards.

Scheme 2

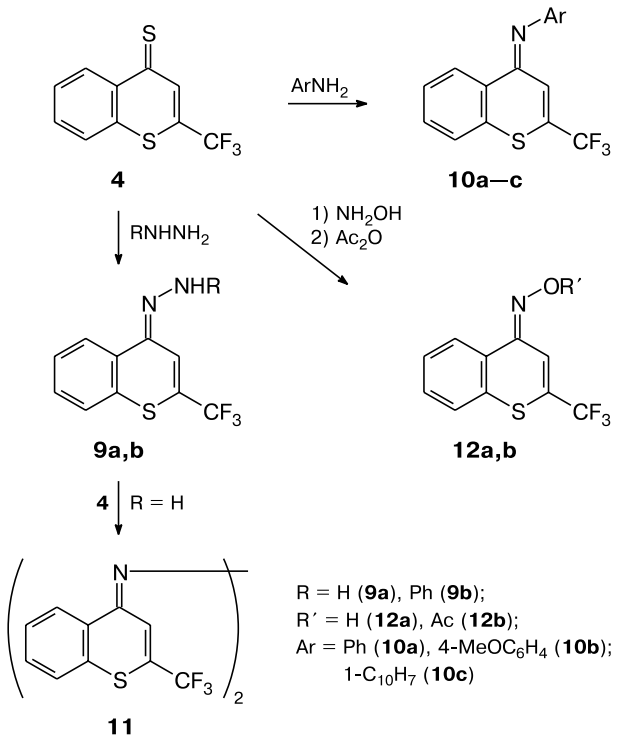


Treatment of thiochromone **3** with hydrazine hydrate at ~20 °C for 20 min gave pyrazole **8** in 62% yield. With consideration that the C(4) atom is the most reactive site in thiochromones,[8] one could assume that this reaction proceeds through intermediate hydrazone **9a**, which then undergoes recyclization into pyrazole **8**. However, an attempted synthesis of compound **9a** from thiochromone **3** by its reaction with hydrazine hydrate at ~0 °C failed (the synthesis of hydrazone **9a** is described below).

Full sulfur analogs of chromones (4*H*-thiochromene-4-thiones or dithiochromones) are poorly studied. It is only known that dithioflavones react with primary aliphatic amines to give thiochromenimines,[11] while unsubstituted dithiochromone isomerizes into dithiocoumarin on heating with P_2S_5.[10] We found that dithiochromone **4** reacts, at the thione group, with aniline, *p*-anisidine, and α-naphthylamine in boiling butanol over 1.5—6 h to give anils **10a**—**c** in 43—79% yields (Scheme 3). In contrast to aromatic amines, ammonia and 2-aminoethanol reacted with dithiochromone **4** ambiguously, causing resinification or the formation of complex inseparable mixtures of products. Although geometrical isomerism is possible for products derived from dithiochromone **4** and aromatic amines, the ^{1}H NMR spectra of anils **10a**—**c** show only one set of signals corresponding to the *E*-configuration of the C=N bond, which is evident from the chemical shift of the H(5) proton (δ 8.62—8.85). In the *Z*-isomer, because of unfavorable steric interactions with the *peri*-H atom, the aromatic substituent should predominantly be out of the plane of the thiochromone system and thus has a shielding effect on the H(5) proton; as the result, its signal would be shifted upfield (in the series of 4-azafluorene azomethines, an analogous proton appears at δ 6.1—6.5).[33]

Treatment of dithiochromone **4** with hydrazine hydrate at ~0 °C gave hydrazone **9a** in 81% yield, which had not been obtained from thiochromone **3**. Dithiochromone **4** reacted with phenylhydrazine in an ethereal solution at

Scheme 3



~20 °C for a day, affording phenylhydrazone **9b** in 57% yield. All attempts at recyclization of hydrazones **9a,b** into the corresponding pyrazoles by heating them in ethanol in the presence of catalytic amounts of HCl resulted in resinification. However, the reaction of hydrazone **9a** with an equimolar amount of dithiochromone **4** in boiling butanol for 6 h gave azine **11** in 60% yield. This compound is negligibly soluble in $CDCl_3$ and DMSO-d_6, which made it impossible to record its high-quality ^{1}H NMR spectrum. Its ^{19}F NMR spectrum in DMSO-d_6 contains three singlets for the CF_3 groups at δ –64.4, –63.2, and –62.6 in the ratio 1 : 3 : 1, respectively; therefore, azine **11** exists as a mixture of two geometrical *E*,*Z*- and *E*,*E*-isomers relative to the C=N bonds, the latter isomer being dominant (2 : 3). Dithiochromone **4** reacted with hydroxylamine as easily as did chromenethione **2**,[9] giving oxime **12a** in 85% yield; when treated with acetic anhydride in the presence of catalytic amounts of conc. H_2SO_4, oxime **12a** underwent O-acetylation into compound **12b** (see Scheme 3). According to ^{1}H NMR data, hydrazones **9a,b** and oxime **12a** exist almost exclusively as *E*-isomers (the signal for the H(5) proton appears at δ 8.12—8.33). Trace amounts (~1%) of the *Z*-isomer were detected only for oxime **12a** (a doublet for the H(5) proton at δ 8.95). In contrast to 2-trifluoromethylchromones, the signal for the H(3) proton in all derivatives of thiochromone **3** appears as a quartet with $^4J_{H,F}$ = 1.0—1.2 Hz.

Thus, despite the presence of the electron-withdrawing CF_3 group at the C(2) atom, thio- and dithiochromones **3** and **4** react with nucleophilic reagents mainly at the C(4) atom, in sharp contrast to chromone **1**, whose most characteristic reactions occur at the C(2) atom and are followed by opening of the pyrone ring. The essential differences between the reactivities of chromone **1** and its sulfur analogs **2**—**4** can be explained with the use of semiempirical PM3 calculations (see Ref. 34). According to the data obtained, the p_z-orbital coefficients on the C(2) and C(4) atoms and the LUMO energies for compounds **1** and **3** differ only slightly. At the same time, the electron-donating S atom in thiochromone **3** increases the electron density on the C(2) atom, thus favoring addition of a nucleophile to the C(4) atom. For the transitions $\mathbf{1} \rightarrow \mathbf{2}$ and $\mathbf{1} \rightarrow \mathbf{4}$, the LUMO energy significantly decreases, with a simultaneous increase in the p_z-orbital coefficients on the C(4) atoms compared to the C(2) atoms; this allows one to predict a predominant nucleophilic attack on position 4 of compounds **2** and **4** (Table 2).

Thus, unlike 2-R^F-chromones we studied earlier,[2] 2-CF_3-thio- and dithiochromones react with N-nucleophiles following mainly the 1,2-addition scheme; this leads to anils, hydrazones, azine, and oxime of 2-CF_3-thiochromone, which are of interest for further investigations into regiocontrolled synthesis of polyfluoroalkyl-containing heterocyclic compounds.

Experimental

IR spectra were recorded on a Perkin—Elmer Spectrum BX-II instrument (KBr pellets). ^{1}H and ^{19}F NMR spectra were recorded on a Bruker DRX-400 spectrometer (400.1 (^{1}H) and 376.5 MHz (^{19}F)) in $CDCl_3$ with Me_4Si and $CFCl_3$, respectively, as the internal standards. The mass spectra of compounds **3**, **5**, and **8** were recorded on a Finnigan MAT 8200 instrument (EI, 70 eV).

2-Trifluoromethyl-4*H*-thiochromen-4-one (3). Dry triethylamine (15.2 g, 0.15 mol) was added for 1 h to a stirred (and cooled on an ice bath) solution of 2-mercaptoacetophenone (7.0 g, 0.046 mol) and trifluoroacetic anhydride (31.5 g, 0.15 mol) in anhydrous THF (50 mL). The reaction mixture was stirred at ~20 °C for 3 h. Then the solvent was removed in aspirator vacuum and a mixture of conc. HCl (20 mL) and ethanol (40 mL) was added to the residue. The resulting mixture was refluxed for 1 h; the solvent was removed and the residue was diluted with water (50 mL). The product was extracted with CH_2Cl_2 (50 mL). The solvent was removed under reduced pressure and the resulting oil was distilled *in vacuo* while collecting a fraction with b.p. 90—95 °C (0.5 Torr). The fraction was mixed with 85% methanol (10 mL) and cooled to −20 °C. The crystalline precipitate that formed was filtered off, washed with aqueous methanol, and dried. The yield was 6.0 g (57%), m.p. 52—53 °C (*cf.* Ref. 28: m.p. 50—52 °C). ^{1}H NMR (400 MHz, $CDCl_3$), δ: 7.33 (q, 1 H, H(3), $^4J_{H,F}$ = 0.8 Hz); 7.62 (ddd, 1 H, H(6), J_o = 8.1 and 6.5 Hz, J_m = 1.9 Hz); 7.68 (ddd, 1 H, H(8), J_o = 8.2 Hz, J_m = 1.9 Hz, J_p = 0.7 Hz); 7.71 (ddd, 1 H, H(7), J_o = 8.2 and 6.5 Hz, J_m = 1.4 Hz); 8.52 (ddd, 1 H, H(5), J_o = 8.1 Hz, J_m = 1.4 Hz, J_p = 0.7 Hz). ^{19}F NMR (376.5 MHz, $CDCl_3$), δ: −65.2 (d, CF_3, $^4J_{F,H}$ = 0.8 Hz). MS (EI, 70 eV), m/z (I_{rel} (%)): 230 $[M]^+$ (89), 202 (100), 183 (34), 136 (61), 108 (44), 69 (29), 28 (50).

2-Trifluoromethyl-4*H*-thiochromene-4-thione (4). A mixture of thiochromone **3** (2.0 g, 8.7 mmol) and P_2S_5 (1.93 g, 8.7 mmol) in dry toluene (10 mL) was refluxed with stirring for 1 h. On cooling, the precipitate that formed was filtered off and washed with toluene, the solvent was removed from the filtrate, and the residue was recrystallized from methanol. The yield of thiochromenethione **4** as dark green needle-shaped crystals was 1.4 g (66%), m.p. 50—51 °C. Found (%): C, 48.56; H, 2.03. $C_{10}H_5F_3S_2$. Calculated (%): C, 48.77; H, 2.05. IR, ν/cm^{-1}: 1630, 1592, 1573. ^{1}H NMR (400 MHz, $CDCl_3$), δ: 7.60 (ddd, 1 H, H(6), J_o = 8.3 and 6.6 Hz, J_m = 1.8 Hz); 7.67 (ddd, 1 H, H(8), J_o = 8.2 Hz, J_m = 1.8 Hz, J_p = 0.5 Hz); 7.71 (ddd, 1 H, H(7), J_o = 8.2 and 6.6 Hz, J_m = 1.4 Hz); 8.16 (q, 1 H, H(3), $^4J_{H,F}$ = 0.9 Hz); 8.88 (ddd, 1 H, H(5), J_o = 8.3 Hz, J_m = 1.4 Hz, J_p = 0.5 Hz). ^{19}F NMR (376.5 MHz, $CDCl_3$), δ: −64.3 (d, CF_3, $^4J_{F,H}$ = 0.9 Hz).

4-Oxo-2-trifluoromethyl-4*H*-thiochromene 1,1-dioxide (5). A mixture of thiochromone **3** (0.50 g, 2.2 mmol), 33% H_2O_2 (3 mL), and AcOH (6 mL) was heated on a water bath for 1 h and then cooled to room temperature. The reaction mixture was diluted with water (20 mL) and the crystalline product was filtered off, washed with water, dried, and recrystallized from cyclohexane. The yield of sulfone **5** as a yellow powder was 0.24 g (42%), m.p. 135—136 °C. ^{1}H NMR (200 MHz, $CDCl_3$), δ: 7.08 (s, 1 H, H(3)); 7.82 (td, 1 H, H(6), J_o = 7.6 Hz, J_m = 1.2 Hz); 7.95 (td, 1 H, H(7), J_o = 7.6 Hz, J_m = 1.3 Hz); 8.08 (dd, 1 H, H(8), J_o = 7.9 Hz, J_m = 1.2 Hz); 8.19 (dd, 1 H, H(5), J_o = 7.9 Hz, J_m = 1.3 Hz). ^{19}F NMR (188 MHz, $CDCl_3$), δ: −61.6 (d, CF_3, $^4J_{F,H}$ = 1.0 Hz). MS (EI, 70 eV), m/z (I_{rel} (%)): 262 $[M]^+$ (20), 193 $[M - CF_3]^+$ (44), 136 (24), 104 (100), 76 (49), 50 (21). Found: m/z 261.9913 $[M]^+$. $C_{10}H_5F_3O_3S$. Calculated: M = 261.9912.

***cis*-2-Trifluoromethylthiochroman-4-ol (6).** A mixture of thiochromone **3** (0.30 g, 1.3 mmol) and $NaBH_4$ (0.3 g, 7.9 mmol) in freshly distilled dry isopropyl alcohol (3 mL) was refluxed for 15 min. The resulting violet solution was filtered, concentrated, and diluted with water (20 mL). The crystalline precipitate was filtered off, washed with water, dried, and recrystallized from hexane. The yield of thiochromanol **6** as colorless (slightly grayish) crystals was 0.16 g (53%), m.p. 104—105 °C. Found (%): C, 51.40; H, 3.66. $C_{10}H_9F_3OS$. Calculated (%): C, 51.28; H, 3.87. IR, ν/cm^{-1}: 3321, 1593, 1570. ^{1}H NMR (400 MHz, $CDCl_3$), δ: 1.90 (dt, 1 H, H(3a), $J_{H(3a),H(3e)}$ = 12.8 Hz, $J_{H(3a),H(2a)} = J_{H(3a),H(4a)}$ = 10.6 Hz); 2.08 (br.s, 1 H, OH); 2.69 (ddd, 1 H, H(3e), $J_{H(3e),H(3a)}$ = 12.9 Hz, $J_{H(3e),H(2a)}$ = 7.2 Hz,

Table 2. LUMO energies E_{LUMO}, p_z-orbital coefficients K_{LUMO}, and charges q for compounds **1**—**4**

Compound	$-E_{LUMO}$ /eV	K_{LUMO}		q	
		C(2)	C(4)	C(2)	C(4)
1	1.15	0.51	0.37	0.00	0.37
2	2.26	0.40	0.56	−0.01	0.01
3	1.44	0.52	0.38	−0.26	0.35
4	2.56	0.40	0.54	−0.28	−0.02

$J_{H(3e),H(4a)}$ = 4.1 Hz); 3.96 (dquint, 1 H, H(2a), $J_{H(2a),H(3a)}$ = 10.3 Hz, $J_{H(2a),H(3e)}$ = $J_{H(2a),CF_3}$ = 7.6 Hz); 4.77 (br.dd, 1 H, H(4a), $J_{H(4a),H(3a)}$ = 10.8 Hz, $J_{H(4a),H(3e)}$ = 3.2 Hz); 7.20—7.28 (m, 3 H, H(6), H(7), H(8)); 7.57—7.61 (m, 1 H, H(5)). ^{19}F NMR (376.5 MHz, $CDCl_3$), δ: −73.3 (d, CF_3, $^3J_{F,H}$ = 7.7 Hz).

2-Trifluoromethyl-4*H*-thiochromen-4-ol (7). Sodium borohydride (0.1 g, 2.6 mmol) was added to a cooled (with ice water) solution of thiochromone **3** (0.25 g, 1.1 mmol) in methanol (6 mL). The mixture was stirred at ~0 °C for 7 min and concentrated in aspirator vacuum without heating. The residue was diluted with water (10 mL). The colorless crystals that formed were filtered off, washed with water, dried, and recrystallized from hexane. The yield of thiochromenol **7** was 0.18 g (72%), m.p. 67—68 °C. Found (%): C, 51.75; H, 3.05. $C_{10}H_7F_3OS$. Calculated (%): C, 51.72; H, 3.04. IR, ν/cm^{-1}: 3212, 1640, 1594, 1571. ^{1}H NMR (400 MHz, $CDCl_3$), δ: 2.17 (d, 1 H, OH, J = 8.0 Hz); 5.32—5.37 (m, 1 H, H(4)); 6.77 (dq, 1 H, H(3), $J_{H(3),H(4)}$ = 4.6 Hz, $J_{H(3),CF_3}$ = 1.3 Hz); 7.30—7.42 (m, 3 H, H(6), H(7), H(8)); 7.60—7.63 (m, 1 H, H(5)).

3(5)-(2-Mercaptophenyl)-5(3)-trifluoromethylpyrazole (8). A mixture of thiochromone **3** (0.20 g, 0.87 mmol) and 80% hydrazine hydrate (0.5 mL) was stirred at ~20 °C for 20 min and then 20% HCl (7 mL) was added. The crystalline product that formed was filtered off, washed with water, dried, and recrystallized from cyclohexane. The yield of pyrazole **8** as yellow crystals was 0.13 g (62%), m.p. 92—93 °C. ^{1}H NMR (200 MHz, $CDCl_3$), δ: 3.62 (s, 1 H, HS); 6.84 (s, 1 H, =CH); 7.27—7.54 (m, 4 H, H arom.); 11.3 (br.s, 1 H, NH). ^{19}F NMR (188 MHz, $CDCl_3$), δ: −63.2 (s, CF_3). MS (EI, 70 eV), m/z (I_{rel} (%)): 244 $[M]^+$ (100), 225 (14), 147 (39), 121 (17), 69 (14). Found: m/z 244.0270 $[M]^+$. $C_{10}H_7F_3N_2S$. Calculated: M = 244.0282.

2-Trifluoromethyl-4*H*-thiochromen-4-one hydrazone (9a). Dithiochromone **4** (0.25 g, 1.0 mmol) was added at ~0 °C to a solution of 98% $N_2H_4 \cdot H_2O$ (0.25 g, 5.0 mmol) in ethanol (5 mL). The reaction mixture was homogenized by stirring it at ~0 °C and then concentrated at this temperature under reduced pressure. The residue was diluted with cold water (5 mL) and the crystalline product was filtered off, washed with water, and dried. The yield of hydrazone **9a** as bright yellow crystals was 0.20 g (81%), m.p. 87—88 °C. Found (%): C, 49.36; H, 2.69; N, 11.41. $C_{10}H_7F_3N_2S$. Calculated (%): C, 49.18; H, 2.89; N, 11.47. IR, ν/cm^{-1}: 3361, 3223, 1637, 1606, 1559, 1532. ^{1}H NMR (400 MHz, $CDCl_3$), δ: 5.54 (br.s, 2 H, NH_2); 7.20 (q, 1 H, H(3), $J_{H,F}$ = 1.2 Hz); 7.27—7.36 (m, 3 H, H(6), H(7), H(8)); 8.11—8.14 (m, 1 H, H(5)).

2-Trifluoromethyl-4*H*-thiochromen-4-one *N*-phenylhydrazone (9b). A solution of dithiochromone **4** (0.30 g, 1.2 mmol) and phenylhydrazine (0.13 g, 1.2 mmol) in Et_2O (3 mL) was kept at ~20 °C for a day. Then the solvent was removed and the solid residue was recrystallized from hexane. The yield of phenylhydrazone **9b** as orange crystals was 0.22 g (57%), m.p. 120—121 °C. Found (%): C, 59.84; H, 3.27; N, 8.72. $C_{16}H_{11}F_3N_2S$. Calculated (%): C, 59.99; H, 3.46; N, 8.74. ^{1}H NMR (400 MHz, $CDCl_3$), δ: 6.95 (br.s, 1 H, NH); 7.17 (br.s, 1 H, H(3)); 7.15—7.40 (m, 8 H, H(6), H(7), H(8), Ph); 8.33 (br.d, 1 H, H(5), J_o = 7.7 Hz). ^{19}F NMR ($CDCl_3$), δ: −66.1 (d, CF_3, $^4J_{F,H}$ = 1.2 Hz).

4-Phenylimino-2-trifluoromethyl-4*H*-thiochromene (10a). A mixture of dithiochromone **4** (0.5 g, 2.0 mmol) and freshly distilled aniline (0.28 g, 3.0 mmol) in dry butanol (3 mL) was refluxed for 6 h, diluted with ethanol (5 mL), and cooled to −10 °C. The resulting yellow needle-shaped crystals were filtered off, washed with ethanol, and dried. The yield of anil **10a** was 0.48 g (79%), m.p. 107—108 °C. Found (%): C, 61.94; H, 3.28; N, 4.61. $C_{16}H_{10}F_3NS \cdot 0.25H_2O$. Calculated (%): C, 62.03; H, 3.42; N, 4.52. IR, ν/cm^{-1}: 1610, 1590, 1572, 1558. ^{1}H NMR (400 MHz, $CDCl_3$), δ: 6.85—6.89 (m, 2 H, H(2′), H(6′)); 7.14 (tt, 1 H, H(4′)); 7.16 (q, 1 H, H(3), $J_{H,F}$ = 1.0 Hz); 7.37—7.42 (m, 2 H, H(3′), H(5′)); 7.45—7.56 (m, 3 H, H(6), H(7), H(8)); 8.63—8.66 (m, 1 H, H(5)).

4-Methoxyphenylimino-2-trifluoromethyl-4*H*-thiochromene (10b) was obtained analogously as bright yellow crystals in boiling butanol over 1.5 h. The yield was 73%, m.p. 102—103 °C. Found (%): C, 59.38; H, 3.63; N, 4.05. $C_{17}H_{12}F_3NOS \cdot 0.5H_2O$. Calculated (%): C, 59.30; H, 3.81; N, 4.07. IR, ν/cm^{-1}: 3063, 1609, 1562, 1554, 1500. ^{1}H NMR (400 MHz, $CDCl_3$), δ: 3.84 (s, 3 H, MeO); 6.84 (d, 2 H, H(2′), H(6′), J_o = 8.9 Hz); 6.94 (d, 2 H, H(3′), H(5′), J_o = 8.9 Hz); 7.25 (q, 1 H, H(3), $J_{H,F}$ = 1.0 Hz); 7.43—7.53 (m, 3 H, H(6), H(7), H(8)); 8.61—8.64 (m, 1 H, H(5)).

4-(1-Naphthylimino)-2-trifluoromethyl-4*H*-thiochromene (10c) was obtained as orange crystals as described for anil **10a**. The yield was 43%, m.p. 105—106 °C (methanol). Found (%): C, 67.35; H, 3.19; N, 3.71. $C_{20}H_{12}F_3NS$. Calculated (%): C, 67.60; H, 3.40; N, 3.94. IR, ν/cm^{-1}: 3056, 1612, 1571, 1504. ^{1}H NMR (400 MHz, $CDCl_3$), δ: 6.86 (dd, 1 H, H(2′), J_o = 7.2 Hz, J_m = 1.0 Hz); 7.14 (q, 1 H, H(3), $J_{H,F}$ = 1.0 Hz); 7.41—7.60 (m, 6 H, H arom.); 7.66 (d, 1 H, H(8′), J_o = 8.3 Hz); 7.89 (t, 2 H, H(6′), H(7′), J_o = 8.1 Hz); 8.84—8.87 (m, 1 H, H(5)).

2-Trifluoromethyl-4*H*-thiochromen-4-one azine (11). A mixture of dithiochromone **4** (0.2 g, 0.8 mmol) and hydrazone **9a** (0.2 g, 0.8 mmol) in dry butanol (3 mL) was refluxed for 6 h. On cooling, the resulting dark red acicular crystals were filtered off, washed with methanol, and dried. The yield of azine **11** was 0.22 g (60%), sublimed at >250 °C. Found (%): C, 52.75; H, 2.12; N, 5.84. $C_{20}H_{10}F_6N_2S_2$. Calculated (%): C, 52.63; H, 2.21; N, 6.14. IR, ν/cm^{-1}: 3069, 1607, 1558, 1533. ***E*,*E*-isomer**: ^{1}H NMR (400 MHz, $CDCl_3$), δ: 7.30—7.60 (m, 3 H, H(6), H(7), H(8)); 8.32 (q, 1 H, H(3), $J_{H,F}$ = 1.1 Hz); 8.64—8.66 (m, 1 H, H(5)). ^{19}F NMR (DMSO-d_6), δ: −64.4, −63.2, −62.6 (all s, CF_3).

2-Trifluoromethyl-4*H*-thiochromen-4-one oxime (12a). Hydroxylamine hydrochloride (0.16 g, 2.3 mmol) and, after 10-min stirring, dithiochromone **4** (0.30 g, 1.2 mmol) were added to a solution of KOH (0.11 g, 2.0 mmol) in ethanol (3 mL). The reaction mixture was stirred at ~20 °C for 20 min, diluted with water (10 mL), and cooled. The precipitate that formed was filtered off, washed with water, dried, and recrystallized from hexane. The yield of oxime **12a** as colorless needle-shaped crystals was 0.25 g (85%), m.p. 146—147 °C. Found (%): C, 48.87; H, 2.52; N, 5.50. $C_{10}H_6F_3NOS$. Calculated (%): C, 48.98; H, 2.47; N, 5.71. IR, ν/cm^{-1}: 3257, 3095, 3018, 1617, 1559. ^{1}H NMR (400 MHz, $CDCl_3$), δ: 7.34—7.44 (m, 3 H, H(6), H(7), H(8)); 7.77 (q, 1 H, H(3), $J_{H,F}$ = 1.1 Hz); 7.88 (br.s, 1 H, OH); 8.12—8.16 (m, 1 H, H(5)).

4-Acetoxyimino-2-trifluoromethyl-4*H*-thiochromene (12b). Oxime **12a** (0.15 g, 0.6 mmol) was dissolved in Ac_2O (3 mL) containing a drop of conc. H_2SO_4. The resulting solution was refluxed for 20 min. On cooling, water (7 mL) and conc. HCl (0.5 mL) were added and the reaction mixture was stirred until

precipitation occurred. The precipitate of the product was filtered off, washed with water, dried, and recrystallized from hexane. The yield of acetate **12b** as colorless crystals was 0.12 g (70%), m.p. 95—96 °C. Found (%): C, 50.33; H, 2.84; N, 4.76. $C_{12}H_8F_3NO_2S$. Calculated (%): C, 50.18; H, 2.81; N, 4.88. IR, ν/cm^{-1}: 3090, 1782, 1612, 1561, 1534. ^1H NMR (400 MHz, $CDCl_3$), δ: 2.33 (s, 3 H, Me); 7.43—7.55 (m, 3 H, H(6), H(7), H(8)); 7.71 (q, 1 H, H(3), $J_{H,F}$ = 1.0 Hz); 8.47—8.50 (m, 1 H, H(5)).

Attempted reduction of compound **12b** with $NaBH_4$ in boiling isopropyl alcohol recovered the starting oxime **12a**.

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