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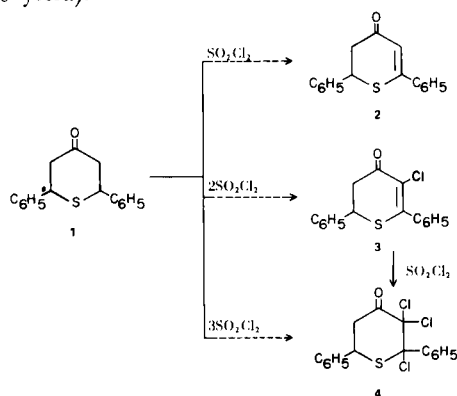
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2,6-Diphenyl-2,3,5,6-tetrahydro-4*H*-thiopyran-4-one was treated with one, two, and three equivalents of sulfuryl chloride in the presence of pyridine to give the dihydrothiopyranone **2**, the 3-chlorodihydrothiopyranone **3**, and the trichlorotetrahydrothiopyranone **4**, respectively. Compound **4** was converted to 3-chloro-2,6-diphenyl-4*H*-thiopyran-4-one by pyrolysis and to 3-hydroxy-2,6-diphenyl-4*H*-thiopyran-4-one on treatment with alcohols. Several pyrylium dyes were prepared from the latter compounds.

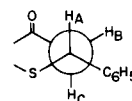
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Chen (1) has shown that 2,6-diphenyl-2,3-dihydro-4*H*-thiopyran-4-one (**2**) can be prepared conveniently from the tetrahydrothiopyran-4-one (**1**) and *N*-chlorosuccinimide (NCS). We had need for substantial amounts of **2** and have investigated replacements for NCS. The present report describes the behavior of **1** when sulfuryl chloride replaced NCS as the oxidizing agent.

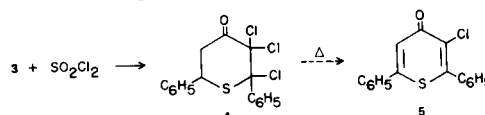
The thiopyranone **1** was treated with one equivalent of sulfuryl chloride and two equivalents of pyridine in methylene chloride at 0°, giving the dihydrothiopyranone, **2**, in 60-70% yield. Since the reaction mixture contained 30-40% of the starting material, the reaction was repeated with two equivalents of sulfuryl chloride and four equivalents of pyridine. The chlorothiopyranone **3** was obtained in 90% yield. These results parallel the results obtained when NCS is used as the oxidizing reagent (1). Increasing the sulfuryl chloride to three or four equivalents resulted in the formation of the trichloro thiopyranone **4** (85% yield).



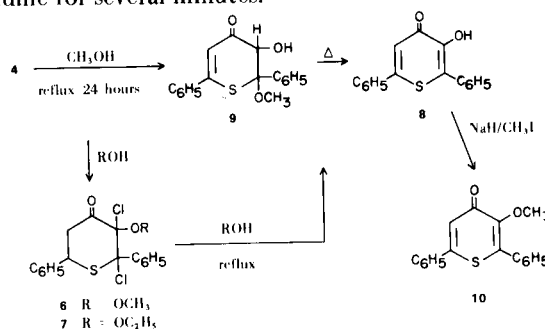
The structures **2** and **3** have been established previously (1). The structure **4** is based on the following evidence. Chlorination of **3** in acetic acid with sulfuryl chloride resulted in the formation of **4**, presumably by the addition of chlorine to the double bond of **3**. Pyrolysis of **4** either neat or in decalin gave the known ketone **5** (**2**), indicating that the basic thiopyranone structure is intact in **4**. The nmr spectrum of **4** showed an AMX pattern. Considering the configuration shown below,



the coupling constants for the hydrogens at C-5 and C-6 are: H_A , *dd*, δ 4.92, $J_{AC} = 13$, $J_{AB} = 4$; H_C , *dd*, δ 3.97, $J_{AC} = 13$, $J_{BC} = 14$; H_B , *dd*, δ 3.15, $J_{AB} = 4$, $J_{BC} = 14$ Hz. This spectrum demonstrates that all of the chlorine atoms are in the 3,4-positions.

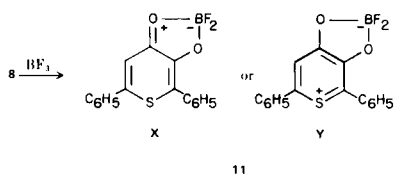


Crystallization of **4** from methanol or ethanol resulted in the replacement of one chlorine by an alkoxy group to give **6** and **7**, respectively. A similar displacement did not occur with isopropyl alcohol. A 93% yield of **6** was obtained by stirring a hot solution of **4** in methanol and pyridine for several minutes.



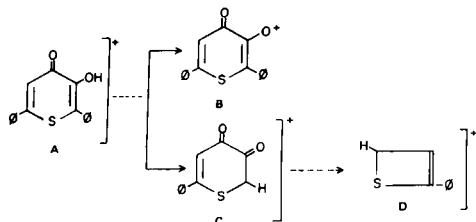
When **4** was refluxed for 24 hours in methanol, an intermediate was obtained to which we assign the structure **9**. This compound was unchanged by crystallization from acetic acid but is converted to **8** by crystallization from acetonitrile or by pyrolysis. The methanol appears to be chemically bound rather than a solvent of crystallization since **8** did not give **9** on crystallization from methanol. Compound **8** was obtained when **9**, **4** or **6** were refluxed in methyl alcohol for 48 hours. The formation of **8** was more rapid in refluxing ethyl alcohol, since the conversion of **4** or **7** required only 20 hours.

The thiopyrone **8** formed a BF_2 complex **11**, a reaction which is characteristic of α -hydroxy ketones (3). Of the two possible structures, X and Y, we prefer the ionic structure Y because its electronic and emission spectra are similar to the spectra of aryl pyrylium salts.

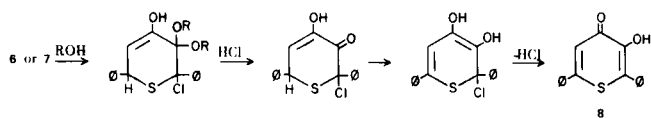


Compound **8** was methylated to give **10**, which in turn was converted to the pyrylium salt **16**.

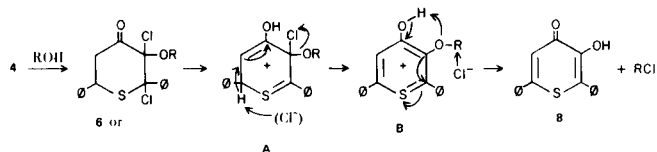
The mass spectrum of **8** is consistent with the assigned structure. Fragmentation occurs by two routes. The primary route involves the loss of a proton to give the stable ion B. In the secondary route, the tautomeric form of A loses a phenyl group to give C, which then loses two carbon monoxide fragments to give D. The mass spectral data are recorded in the experimentation section.



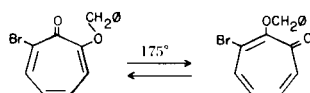
There are several reaction paths by which **6** or **7** would give **8**. Probably the most direct is the following.



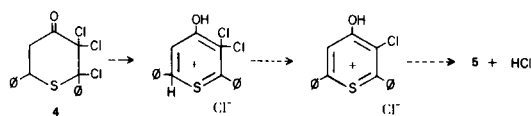
A more interesting alternative is the hydroxy-assisted dealkylation depicted below.



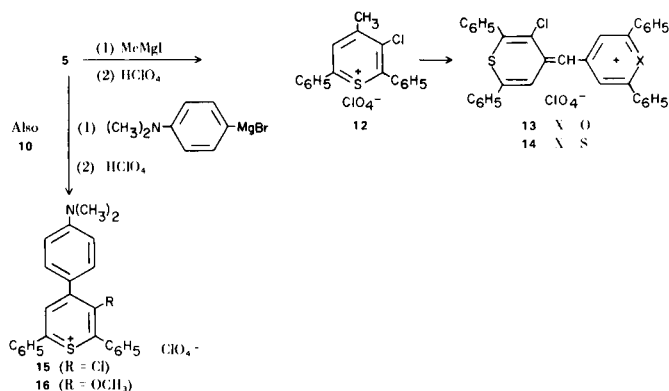
A similar inter-oxygen alkyl migration in the thermolyses of tropolone ethers has recently been reported (4).



The latter reaction path (excluding the dealkylation step) can also be used to rationalize the formation of **5** by the pyrolysis of **4**.



Our continued interest in the spectral properties of pyrylium salts prompted us to convert the pyrones **5** and **10** to some pyrylium dyes. Treatment of **5** with methyl magnesium iodide gave the methyl pyrylium salt **12**, from which the two monomethine dyes **13** and **14** were easily prepared by reaction with the appropriate pyrone or thiopyrone in the presence of acetic anhydride. The pyrylium salts **15** and **16** resulted from the reaction of **5** or **10** with *p*-dimethylaminophenyl magnesium bromide.



The electronic spectral absorption data are collected in Table I. Comparison of **13**, **14**, **15**, and **16** is made with the corresponding dyes which have no chlorine or methoxy group in the 3-position. The presence of a chlorine atom affects only the long-wavelength absorption causing, in all cases, a marked reduction in the molecular-extinction coefficient. The presence of the chlorine atom in **15** produces a pronounced bathochromic shift in the long-wavelength absorption; the methoxy group in **16** resulted in a bathochromic shift with little change in the extinction coefficient and some changes in the shorter-wavelength absorptions.

EXPERIMENTAL

Melting points were determined in a Mel-Temp apparatus and are uncorrected. The electronic absorption spectra were recorded on a Cary Model 17 spectrometer, the proton spectra with a Bruker Model HX-90 instrument, and the mass spectra with a Hitachi Model RMS-4 spectrometer.

The *trans* isomer of **1** (m.p. 87-88°) was used.

2,6-Diphenyl-2,3-dihydro-4*H*-thiopyran-4-one (**2**).

A solution of 5.4 g. (0.02 mole) of **1** in 50 ml. of methylene chloride containing 3.7 ml. (3.16 g., 0.04 mole) of pyridine was cooled to -4° and 1.63 ml. (2.72 g., 0.02 mole) of sulfuric chloride in 10 ml. of methylene chloride was added dropwise, keeping the temperature below 0°. Stirring was continued for one hour and the temperature allowed to rise to 8°. The methylene chloride solution was washed with water, dried, and evaporated. A tlc (silica-gel, benzene) showed only product and starting material. The yield of **2** was determined by oxidation with selenium oxide (1) to give 2,6-diphenyl-4*H*-thiopyran-4-one in 65% yield.

3-Chloro-2,6-diphenyl-5,6-dihydro-4*H*-thiopyran-4-one (**3**).

Table I

Electronic Absorption Spectra in Acetonitrile [λ max ($\epsilon \times 10^{-3}$)]

Compound No.					
13 unchlorinated	226 (30.3)	253 (32.3)	385 (18.2)	553 (62.0)	582 (67.2)
		263 (48.0)	395 (40.0)	~ 555 (64.0)	593 (193)
14 unchlorinated	244 (41.4)	253 (39.0)	390 (18.6)		622 (78.0)
	242 (31.0)	255 (28.7)	390 (20.8)		622 (113.5)
15 unchlorinated	248 (15.3)	272 (19.7)	386 (11.3)		617 (35.0)
	243 (16.4)	259 (18.8)	380 (15.7)		577 (59.2)
16	245 (17.0)		335 (13.5)	415 (12.0)	608 (54.0)
	243 (16.4)		380 (15.7)		577 (59.2)

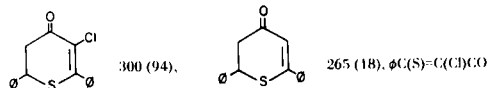
The above procedure was used with the following quantities: 5.4 g. (0.02 mole) of **1**, 5 ml. (0.06 mole) of pyridine, and 3.3 ml. (0.04 mole) of sulfuryl chloride. The yield of **3** was 5.3 g. (90%), m.p. 95-98°. The ir spectrum matched that of a sample prepared by Reynolds (6). The mass spectral data m/e (relative intensity) are: M^+ 300 (70%), $m-\phi$ 283 (15), $m-\text{Cl}$ 265 (14), $\phi\text{C}(\text{S})=\text{C}(\text{Cl})\text{CO}$ 196 (40), $\phi\text{CS}=\text{CCl}$ 168 (100), $\phi\text{C}(\text{S})=\text{CH}$ 134 (40), ϕCS 121 (25), $\phi\text{CH}=\text{CH}_2$ 104 (30).

2,6-Diphenyl-2,3,3-trichloro-5,6-dihydro-4H-thiopyran-4-one (**4**).

(a) The procedure described for **2** was used with the following quantities: 5.4 g. (0.02 mole) of **1**, 5 ml. (0.06 mole) of pyridine and 4.9 ml. (0.06 mole) of sulfuryl chloride. The yield of **4** was 4.2 g. (57%).

(b) The amount of sulfuryl chloride and pyridine was increased to 0.08 mole. The yield of **4** was 6.1 g. (82%), m.p. 126° (from acetic acid or 2-propanol).

The mass spectral data are: M^+ 370 (31), 196 (59), $\phi\text{C}(\text{S})=\text{CCl}$



168 (100), ϕCS 121 (55), $\phi\text{CH}=\text{CH}_2$ 104 (98).

Anal. Calcd. for $\text{C}_{17}\text{H}_{13}\text{Cl}_3\text{OS}$: C, 54.9; H, 3.5; Cl, 28.6. Found: C, 54.7; H, 3.6; Cl, 28.9.

3-Chloro-2,6-diphenyl-4H-thiopyran-4-one (**5**).

(a) A mixture of 10 g. of **4** and 40 ml. of decalin was heated at reflux for two hours. After the mixture was cooled, 40 ml. of ligroin was added. The crystalline precipitate was collected, yield 6.1 g. (81%), m.p. 116-117° (from methanol); reported m.p. 119° (2).

(b) Ten g. of **4** was heated at 150° for 0.5 hour. The residue was taken up in high-boiling ligroin, and after the solution was cooled, 6.2 g. of product was obtained. The ir was identical to that of the material obtained by procedure (a).

2,3-Dichloro-2,6-diphenyl-3-methoxy-5,6-dihydro-4H-thiopyran-4-one (**6**).

A mixture of 3.8 g of **4** in 25 ml. of methanol and 3 ml. of pyridine was heated to complete solution. After about one minute, the reaction mixture solidified. After the mixture was cooled, the product was collected, yield 3.2 g. (84%), m.p. 156° (from 2-propanol).

Anal. Calcd. for $\text{C}_{18}\text{H}_{16}\text{Cl}_2\text{O}_2\text{S}$: C, 58.9; H, 4.4; Cl, 19.4. Found: C, 58.7; H, 4.4; Cl, 19.4.

2,3-Dichloro-2,6-diphenyl-3-ethoxy-5,6-dihydro-4H-thiopyran-4-one (**7**).

A solution of 0.5 g. of **4** in 8 ml. of ethanol was refluxed 2 minutes. After the mixture stood overnight, the product was collected, yield 0.3 g., m.p. 118° (from ethanol).

Anal. Calcd. for $\text{C}_{19}\text{H}_{18}\text{Cl}_2\text{O}_2\text{S}$: C, 59.8; H, 4.8; Cl, 18.6. Found: C, 59.5; H, 4.7; Cl, 18.7.

3-Hydroxy-2,6-diphenyl-4H-thiopyran-4-one (**8**).

(a) Two g. of **4** was extracted with methanol in a Soxhlet extractor until the solid was completely dissolved. The solid **9** which was obtained from the extract corresponds to the methanol adduct of **8**, yield 1.7 g., m.p. 145-146°.

Compound **9** was unchanged on crystallization from acetic acid but was converted to **8** on crystallization from acetonitrile. Heating at 150° also converted **9** to **8** in 82% yield.

Anal. Calcd. for $\text{C}_{18}\text{H}_{16}\text{O}_3\text{S}$: C, 69.3; H, 5.2. Found: C, 69.5; H, 4.9.

(b) A mixture of 1 g. of **4** or **7** and 10 ml. of ethyl alcohol was refluxed for about 20 hours, giving **8** in 92% yield.

(c) A mixture of 1 g. of **9** and 25 ml. of methyl alcohol was refluxed. After 48 hours, **9** was no longer present (tlc, silica gel, methylene chloride). The mixture was chilled yielding **8** (88%).

(d) The procedure described in c was repeated with **4** and with **6**, and **8** was obtained in about 90% yield; ms: A 280 (100%), B 279 (85%), C 203 (50), D 147 (16), ϕCS (7.7), ϕCO (22), $\phi\text{C}=\text{CH}$ 102 (7.7).

Anal. Calcd. for $\text{C}_{17}\text{H}_{12}\text{O}_2\text{S}$: C, 72.8; H, 4.3. Found: C, 72.5; H, 4.4.

4-Methoxy-2,6-diphenyl-4H-thiopyran-4-one (**10**).

A mixture of 1 g. of **8**, 0.7 g. of sodium hydride (57% dispersion in mineral oil), and 25 ml. of dry tetrahydrofuran was stirred for 1 hour and then 2 ml. of methyl iodide was added. The mixture was stirred for 2 days, poured into aqueous ammonium chloride, and extracted with ether. The extract was dried (magnesium sulfate), the solvent removed, and the residue recrystallized from benzene-hexane giving 0.6 g. of **10**, m.p. 99-100°; ms: M^+ 294, M-OH 277 and 217.

Anal. Calcd. for $\text{C}_{18}\text{H}_{14}\text{O}_2\text{S}$: C, 73.4; H, 4.8; S, 10.9. Found: C, 73.2; H, 4.7; S, 11.3.

2,6-Diphenyl-3-difluoroboryloxy-4H-thiopyran-4-one (**11**).

A mixture of 2 g. of **8** in 8 ml. of boron trifluoride etherate was heated to complete solution. After about one minute, a

yellow precipitate separated, and it was collected and crystallized from acetic acid to give 1.9 g. of **11**, m.p. 195°; uv: λ max ($\epsilon \times 10^{-3}$) 275 (6.9), 390 (24.6); ms: M^+ 328 (100%), m-1 327 (85), m- ϕ 251 (54), C_6H_5CO 105 (54).

Anal. Calcd. for $C_{17}H_{11}BF_2O_2S$: C, 62.4; H, 3.4; S, 9.8. Found: C, 62.5; H, 3.6; S, 10.2.

3-Chloro-4-methyl-2,6-diphenylthiopyrylium Perchlorate (**12**).

A Grignard reagent was prepared from 2 g. of methyl iodide and 1.3 g. of magnesium in ether. A solution of 4 g. of **5** in 50 ml. of dry tetrahydrofuran was added, and the mixture was refluxed for 2 hours, cooled, and poured into dilute perchloric acid. The solid was collected and crystallized from acetic acid, yield 4.0 g. (93%), m.p. 150-151°.

Anal. Calcd. for $C_{18}H_{14}Cl_2O_4S$: C, 54.4; H, 3.6; S, 8.1. Found: C, 54.1; H, 3.7; S, 8.4.

4-[(2,6-Diphenyl-4*H*-pyran-4-ylidene)methyl]3-chloro-2,6-diphenylthiopyrylium Perchlorate (**13**).

A mixture of 0.5 g. of **12** and 0.58 g. of 2,6-diphenyl-4*H*-pyran-4-one in 5 ml. of acetic anhydride was refluxed for 0.5 hour. After the mixture was cooled, the solid was collected and crystallized from acetic anhydride to give 1.1 g. of product, m.p. 265-266°.

Anal. Calcd. for $C_{35}H_{24}Cl_2O_5S$: C, 67.0; H, 3.9; Cl, 11.3. Found: C, 66.9; H, 3.8; Cl, 11.2.

4-[(3-Chloro-2,6-diphenyl-4*H*-thiopyran-4-ylidene)methyl]-2,6-diphenylthiopyrylium Perchlorate (**14**).

A mixture of 0.9 g. of **12** and 1.1 g. of 2,6-diphenyl-4*H*-thiopyran-4-one in 10 ml. of acetic anhydride was refluxed for 0.5 hour. The solution was chilled and the product was collected; yield 1.0 g., m.p. 110°.

Anal. Calcd. for $C_{35}H_{23}Cl_2O_4S_2$: C, 65.9; H, 3.6. Found: C, 65.8; H, 3.9.

3-Chloro-4-(4-dimethylaminophenyl)-2,6-diphenylthiopyrylium Perchlorate (**15**).

A Grignard solution was prepared from 1.2 g. (0.06 mole) of *p*-bromodimethylaniline and 0.15 g. (0.06 mole) of magnesium in 20 ml. of tetrahydrofuran. A solution of 1.5 g. (0.05 mole) of **5** in tetrahydrofuran was added to the Grignard reagent, and stirring was continued for 3 hours. The reaction mixture was poured into dilute perchloric acid, and the solution was allowed to stand for several hours; the solid was then collected and crystallized from acetonitrile to give 2.3 g. of **15**, m.p. 150-151°.

Anal. Calcd. for $C_{25}H_{21}Cl_2NO_4S$: C, 59.8; H, 4.2; N, 2.8. Found: C, 59.9; H, 4.2; N, 2.7.

4-(4-Dimethylaminophenyl)-3-methoxy-2,6-diphenylthiopyrylium Perchlorate (**16**).

The method used for preparing **15** was used with **10** on a 1 mmole scale giving **16** in 56% yield, m.p. 226-227°.

Anal. Calcd. for $C_{26}H_{24}ClNO_5S$: C, 62.7; H, 4.9; N, 2.8. Found: C, 62.9; H, 5.0; N, 2.7.

Acknowledgement.

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REFERENCES AND NOTES

- (1) C. H. Chen, G. A. Reynolds, and J. A. Van Allan, *J. Org. Chem.*, **42**, 2777 (1977).
- (2) F. Arndt, P. Nachtwey, and J. Pusch, *Ber.*, **58**, 1633 (1925).
- (3) J. A. Van Allan and G. A. Reynolds, *J. Heterocyclic Chem.*, **6**, 29 (1969).
- (4) R. Harrison, J. Hobson, and A. Midgley, *J. Chem. Soc., Perkin Trans. I*, 2403 (1976).
- (5) C. A. R. Baxter and D. A. Whiting, *J. Chem. Soc.*, 1174 (1968).
- (6) G. A. Reynolds, *J. Heterocyclic Chem.*, **12**, 755 (1975).