Scientific paper

New Reactions of β-oxo Sulfenyl Chlorides With 2,4-bis(4-methoxyphenyl)-1,3,2,4-dithiadiphosphetane-2,4-disulfide and Phosphorus Pentasulfide

Mohamed I. Hegab*

Photochemistry Dept., National Research Centre, Dokki, 12622 Cairo, Egypt.

** Corresponding author: E-mail: apmihegab65@yahoo.com*

Received: 03-05-2006

Abstract

2,2-Disubstituted 3-chloro-4-oxochromane-3-sulfenyl chlorides (**2a,b**) reacted with Lawesson's reagent (**3**) to afford the unprecedented 4-oxochromane phosphoro(dithioperoxo)thioic chlorides (**5a,b**) and not the β-thiooxo sulfenyl chlorides (**6a,b**). Whereas, sulfenyl chlorides (**2a,b**) gave 1,2,5,6-tetrathiocines (**7a,b**) along with 1,2,3,4-tetrathiins (**8a,b**) when they were treated with phosphorus pentasulfide. However, chlorination of 1,2,5,6-tetrathiocine (**7a**) with sulfuryl chloride afforded the 3,4-dichloro-3,4-disulfenyl dichloride (**12**) along with the 3,4-disulfenyl dichloride (**13**).

Keywords: 3-Chloro-4-oxochromane-3-sulfenyl chloride, Lawesson's reagent, tetrathiocine, tetrathiin, disulfenyl chloride.

1. Introduction

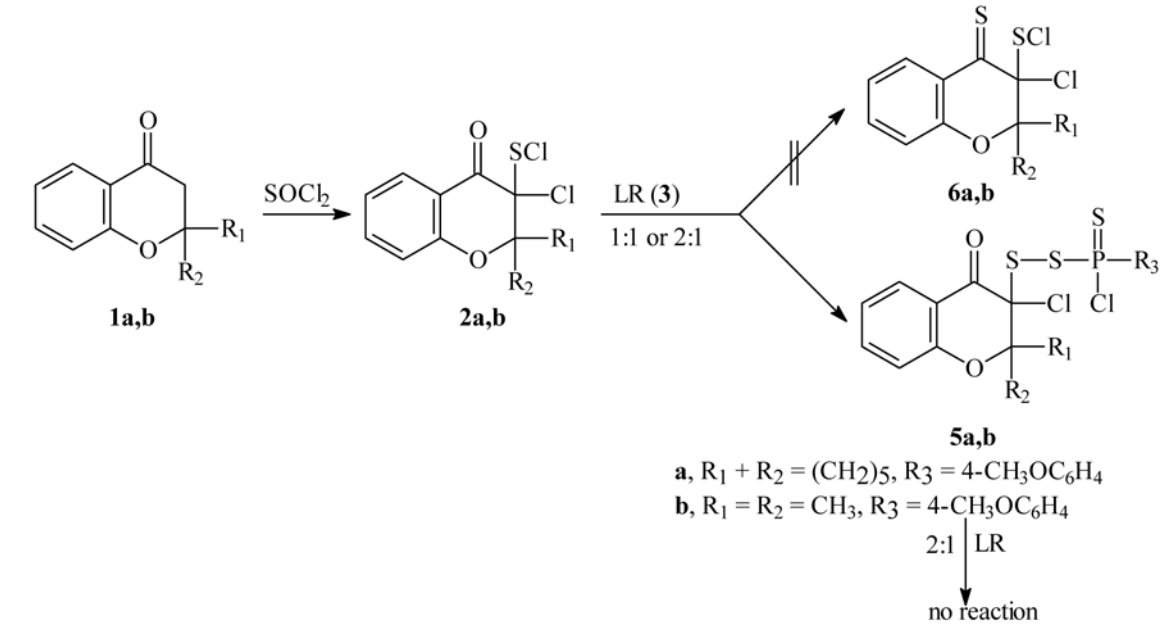
β-Oxo α-chlorosulfenyl chlorides are versatile intermediates for the formation of α-chlorosulfenamides,[1,2] thione *S*-imides,[3,4] dithiiranes/thiosulfines,[5] thione *S*-ylides,[6] thiapyranes,[7] and thiadiazoles.[8] Many reactions of sulfenyl chlorides with nucleophilic reagents, thioketones, 1,3-butadienes, alkenes, disulfides, and with diselenides have been reported.[9] The formation of a symmetrical cyclic tetrasulfide *via* the oxidative coupling of dithiol with cesium fluoride-Celite has been also described.[10]

In the course of continuing study of the chemistry of 3-chloro-2,2-dialkylchroman-4-one-3-sulfenyl chloride, it would be interesting to investigate the chemistry of β-oxo sulfenyl chlorides **2a,b** towards Lawesson's reagent (LR) and phosphorus pentasulfide.

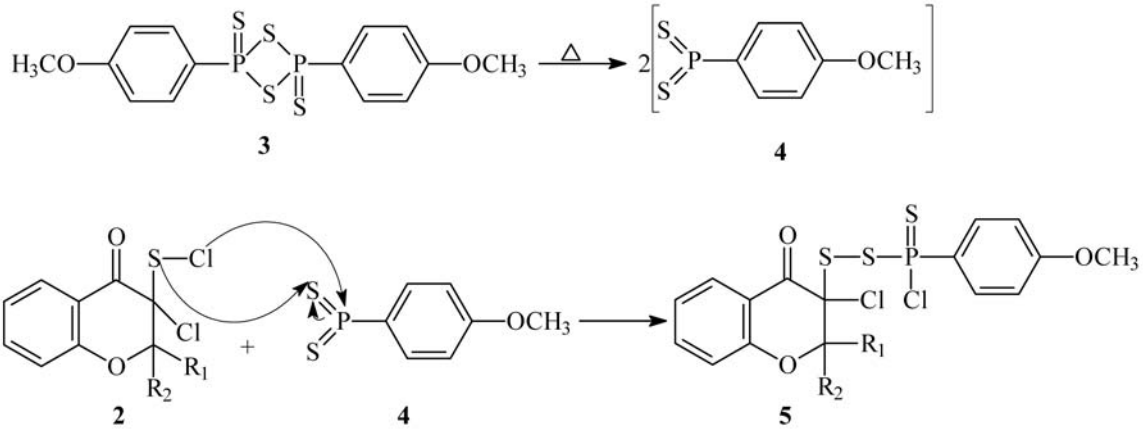
2. Results and Discussion

Reaction of β-oxo sulfenyl chlorides **2a,b** with LR in 2:1 or 1:1 ratio (see experimental part) in dry toluene under reflux gave, surprisingly, the 4-methoxyphenyl-3-[3-chloro-2,2-disubstituted chromano-4-oxo]phospho-ro(dithioperoxo)thioic chlorides **5a,b**, respectively, and not the 2,2-disubstituted-3-chloro chromano-4-thioxo-3-sulfenyl chlorides **6a,b** (see Scheme 1). The formation of phosphorus derivatives **5a,b** could be explained presumably, by the addition of the sulfenyl chloride group to the double bond of the phosphorus sulfide of intermediate **4** to leave the carbonyl group inact (see Scheme 2).

The structures of **5a,b** were confirmed by the spectroscopic data (IR, ^{1}H,^{13}C, and ^{31}P NMR, and MS) as well as elemental analyses (see Experimental part). The IR spectrum of **5a** reveals a strong band at ν = 1704 cm^{-1} for the carbonyl group. ^{1}H NMR spectrum of **5a** exhibits for the cyclohexyl protones as a multiplet signal at δ = 1.17–2.47, and methoxy protons at δ = 3.85 as a singlet signal, in addition to the expected aromatic protons. ^{13}C NMR spectrum of **5a** adds a good support for the established structure. Whereas, the five cyclohexyl methylene carbons appear at δ = 20.79, 21.17, 24.91, 27.93, and 30.94, which might be, due to the presence of the cyclohexane ring as a chair form. O*C*H$_3$, *C*–2, and *C*–3 atoms are recognized at δ = 55.61, 86.33, and 113.74, respectively. Moreover, ^{31}P NMR spectrum of **5a** shows phosporus chemical shift at δ = 88.81.



Scheme 1



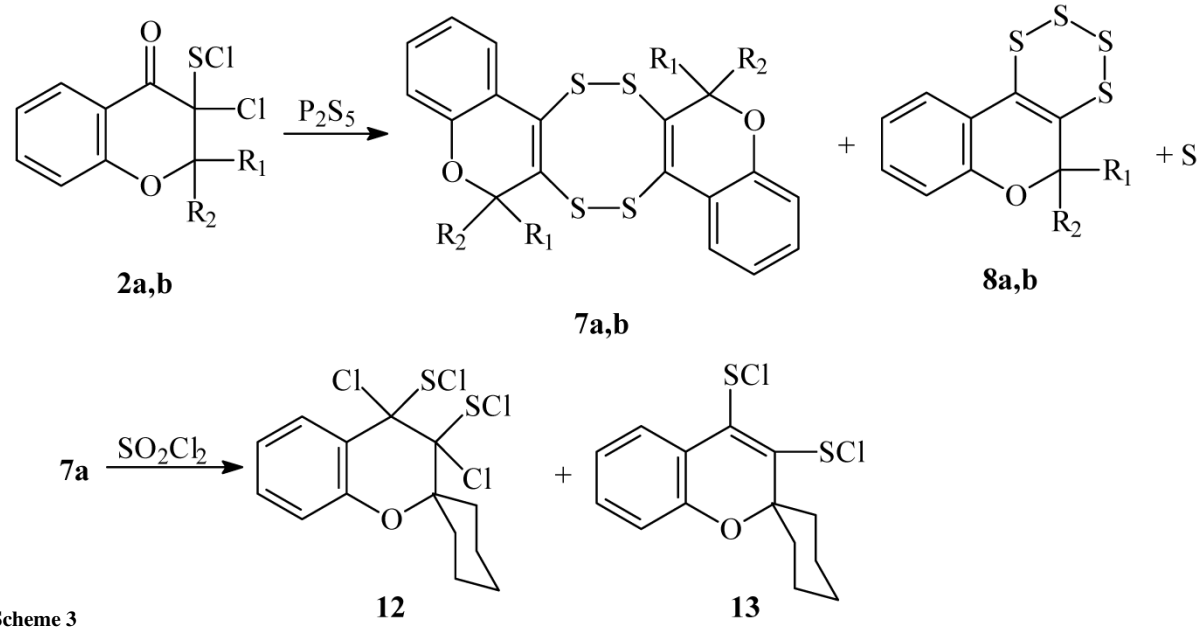
Scheme 2

^{1}H NMR spectrum of **5b** exhibits two methyl protons as two singlet signals at δ = 1.72, and 1.80, and signal for methoxy protons at δ = 3.85 as a singlet signal, besides the expected aromatic protons. In fact, products **5a,b** exhibited clearly the NMR signals of only one diastereomer (see Experimental part). If the minor diastereomer was present, its concentration was too small to be detected. ^{13}C NMR spectrum of **5b** reveals two methyl carbons at δ = 22.50, and 24.32. O*C*H$_3$, *C*–2, and *C*–3 carbons are recognized at δ = 55.59, 85.81, and 113.72, respectively. Again, ^{31}P NMR spectrum of **5b** shows phosporus chemical shift at δ = 88.60.

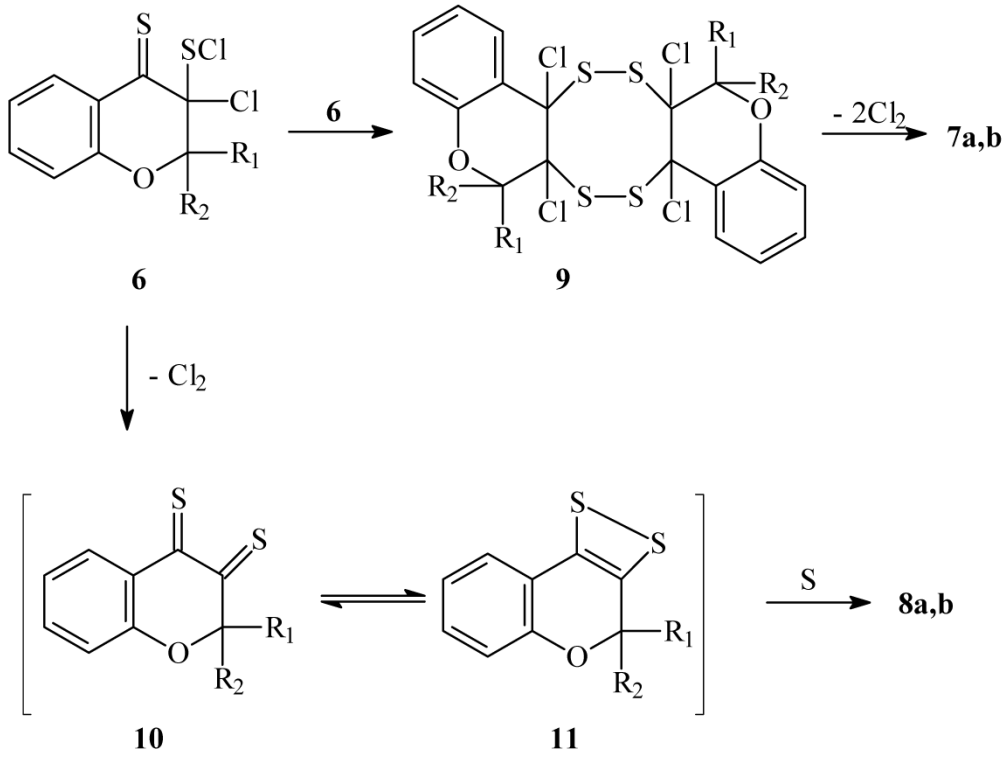
The β-oxo sulfenyl chlorides **2a,b** afforded 1,2,5,6-tetrathiocines **7a,b**, 1,2,3,4-tetrathiins **8a,b** and sulfur when they were heated under reflux with phosphorus pentasulfide in toluene (see Scheme 3). The formation of **7a,b** and **8a,b** could be explained, presumably, by converting the oxo group of **2** to the thiooxo group to give the unstable β-thiooxo sulfenyl chloride **6,** which further reacts by two alternative pathways: a) the active sulfenyl chloride group of two molecules of **6** could be added to the thiooxo groups *via* intermolecular addition to give tetrachloro tetrathiocine **9**, which loses chlorine gas to afford **7**; b) The β-thiooxo sulfenyl chloride **6** loses chlorine gas to give 1,2-dithiooxo intermediate **10** which is in equilibrium with 1,2-dithiate intermediate **11**, and then sulfur could be inserted to **10** or **11** to obtain product **8** (see Scheme 4).

However, chlorination of **7a** with sulfuryl chloride (SO_2Cl_2) in CCl_4 afforded 3,4-dichloro-3,4-disulfenyl dichloride **12** along with 3,4-disulfenyl dichloride **13** (see Scheme 3). These products (**12** and **13)** are stable and

could be separated by silica gel column chromatography. This is in accordance with literature reports for 1,2-dichloro-1,2-disulfenyl dichlorides.[11] The IR spectrum of derivative **7a** did not show any absorption band corresponding to the C=O group. ^{1}H NMR spectrum of **7a** showed cyclohexyl protons at δ = 1.30–2.03 as a multiplet signal, beside the expected aromatic protons. ^{13}C NMR spectrum of **7a** reveals the chemical shifts for C–2′, and C–2′′ carbons at δ = 80.54, for C–3′, and C–3′′ catrbons at δ = 126.43, and for C–4′, and C–4′′ carbons at δ = 128.18. Mass spectrum of **7a** showed the prominent ion peak at *m/z* 458 (M^+ – 2SH). ^{1}H NMR spectrum of **8a** showed only absorptions for cyclohexyl protons and aromatic protons. ^{13}C NMR spectrum of **8a** showed



Scheme 3



Scheme 4

absorptions for C–2´, C–3´, and C–4´ carbons, at δ = 80.76, 125.26, and 137.80 respectively. Mass spectrum of **8a** reveals the prominent ion peaks at *m/z* 326 (M^+) and 198. ^{1}H NMR spectrum of **7b** reveals the presence of four CH_3 protons at δ = 1.58, whereas the ^{13}C NMR of **7b** showed signals for four CH_3 carbons at δ = 23.01, signals for C–2, and C–2´ carbons at δ = 80.61, for C–3, and C–3´ carbons at δ = 126.43, and for C–4, and C–4´ carbons at δ = 128.16. ^{1}H NMR spectrum of **8b** showed absorption for two CH_3 groups at δ = 1.65, and ^{13}C NMR spectrum of **8b** showed absorption for two CH_3 carbons at δ = 22.49, and for C–2, C–3, and C–4 carbons at 80.76, 125.26, and 137.88 respectively.

Spectral data as well as elemental analysis confirmed the structure of **12**. ^{1}H NMR spectrum of **12** reveals cyclohexyl protons as multiplet at δ = 1.23–2.22. Actually, **12** exhibited clearly the NMR signals of only one diastereomer (see Experimental part). If the minor diastereomer was present, its concentration was too small to be detected. ^{13}C NMR spectrum of **12** showed C–2´, C–3´, and C–4´ carbons at δ = 87.79, 92.14, and 95.23 respectively. Finally, the ^{1}H NMR spectrum of **13** showed absorption for cyclohexyl protons as multiplet at δ = 1.25–2.223 in addition to the expected aromatic protons. ^{13}C NMR spectrum of **13** reveals C–2´, C–3´, and C–4´ carbons, at δ = 87.90, 113.16, and 114.21 respectively.

3. Experimental

Melting point is uncorrected and recorded on a digital Electrothermal IA 9000 SERIES melting point apparatus (Electro thermal, Essex, U.K.). Microanalyses were performed with all final compounds on Elementar-Vario EL, Microanalytical Unit, Central Services Laboratory, National Research Centre, Cairo, Egypt. The NMR spectra were recorded on a Varian Mercury VX-300 NMR spectrometer. ^{1}H spectra were performed at 300 MHz and ^{13}C NMR spectra at 75 MHz in $CDCl_3$ as solvent. Chemical shifts are quoted in δ and were related to that of the solvents (Cairo University, Faculty of Science). Splitting patterns were designated as follow: s singlet; d doublet; t triplet; m multiplet. Mass spectra were recorded on Schimadzu GCMS-QP 1000EX (EI, 70 eV) and Hewlett-Packard (EI, 70 eV) spectrometers. IR spectra were obtained with Brucker-Vector 22 for neat samples (for liquids) or KBr wafers (for solid) (Microanalytical Centre of Cairo University). Compounds **1a**,[12] **1b**,[13] **2a,b** [1] were prepared according to the literature procedures.

Reaction of β-oxo α-chloro sulfenyl chlorides (2) with Lawesson's reagent (3). A mixture of β-oxo α-chloro sulfenyl chloride **2a** or **2b** (5 mmol) and Lawesson's reagent **3** (2.5 or 5 mmol) in 20 ml toluene was refluxed for 6 h. The solution was evaporated under vacuum and the crude product was chromatographed on a silica gel column with diethyl ether-petroleum ether (40–60) 1:5 (v:v) as an eluent.

4-Methoxyphenyl-3-[3-chloro spirochroman (2,1´)cyclohexane-4-oxo]phosphoro-(dithioperoxo) thioic chloride (5a). Prepared from **2a**. Colorless crystals, yield 50%, m.p. 175–176 °C. Anal. Calcd for $C_{21}H_{21}Cl_2O_3PS_3$ (519.45): C 48.55, H 4.07, Cl 13.65, P 5.96, S 18.52. Found: C 48.38, H 3.89, Cl 13.51, P 5.59, S 18.35. IR (*v*, cm^{-1}): 1704 (C=O). ^{1}H NMR ($CDCl_3$) δ 1.17–2.47 (m, 10H, cyclohexyl H), 3.85 (s, 3H, OCH_3), 6.80–7.07 (m, 4H, Ar H), 7.45–7.56 (m, 1H, Ar H), and 7.60–8.00 (m, 3H, Ar H). ^{13}C NMR ($CDCl_3$) δ 20.79, 21.17, 24.91, 27.93, 30.94, 55.61, 86.33, 113.74, 113.83, 113.97, 114.06, 118.03, 122.16, 129.19, 133.45, 133.64, 136.44, 136.48, 156.46, 163.77, and 188.36. ^{31}P NMR ($CDCl_3$) δ 88.81. EIMS *m/z* (%): 458 (M^+ – 2S, $2Cl^{37}$, 6), 456 (M^+ – 2S, $Cl^{35,37}$, 39), 454 (M^+ – 2S, $2Cl^{35}$, 45), 419 (55), 265 (12), 233 (13), 213 (15), 205 (100), 173 (21), 155 (12), 121 (37), and 64 (6).

4-Methoxyphenyl-3-[3-chloro 2,2-dimethylchromano-4-oxo]phosphoro-(dithiope-roxo)thioic chloride (5b). Prepared from **2b**. Colorless viscous oil, yield 36%. IR (*v*, cm^{-1}) 1701 (C=O). Anal. Calcd for $C_{18}H_{17}Cl_2O_3PS_3$ (479.39): C 45.09, H, 3.57, Cl 14.79, P 6.46, S 20.06, Found: C 44.88, H 3.50, Cl 14.65, P 6.25, S 19.80. ^{1}H NMR ($CDCl_3$) δ 1.72 (s, 3H, 2–CH_3), 1.80 (s, 3H, 2–CH_3), 3.85 (s, 3H, OCH_3), 6.80–7.10 (m, 4H, Ar H), 7.40–7.56 (m, 1H, Ar H), and 7.85–8.00 (m, 3H, Ar H). ^{13}C NMR ($CDCl_3$) δ 22.45, 24.25, 55.59, 85.88, 113.72, 113.83, 113.98, 114.04, 118.06, 122.16, 129.18, 133.46, 133.64, 136.44, 136.48, 156.46, 163.78, and 188.36. ^{31}P NMR ($CDCl_3$) δ 88.61. EIMS *m/z* (%): 419 (M^+ – 2S, $2Cl^{37}$, 2), 417 (M^+ – 2S, $Cl^{35,37}$,18), 415 (M^+ – 2S, $2Cl^{35}$, 100), 381 (20), 379 (56), 225 (13), 193 (14), 173 (15), 155 (12), 121 (100), and 64 (55).

Reaction of β- oxo α- chloro sulfenyl chloride 2 with phosphorus pentasulfide. A mixture of β-oxo α-chloro sulfenyl chloride **2a** or **2b** (10 mmol) and phosphorus pentasulfide (16 mmol) in 50 ml toluene was heated under refluxe for 10 h. Then the solution was evaporated *in vacuo* and the crude product was chromatographed on a silica gel column with diethyl ether-petroleum ether (40–60) (1:10) as an eluent to obtain the products (in the order of their elution). Sulfur was separated as first component.

2H, 10H-[1,2,5,6]tetrathiocino[3,4-c:7,8-c´]dispirochromene-2,1´-cyclohexane (7a). Prepared from **2a**. Orange oil, yield 72%. Anal.calcd for $C_{28}H_{28}O_2S_4$ (524.76): C 64.08, H 5.38, S 24.44. Found: C 63.78, H 5.28, S 24.05. IR (*v*, cm^{-1}) 2934, 2859, 1478, 1449, 1272, 1236, 1119, and 755. ^{1}H NMR ($CDCl_3$) δ 1.30–2.03 (m,

20H, 2-cyclohexyl H), 6.93–6.99 (m, 2H, Ar H), 7.19–7.31 (m, 5H, Ar H), and 7.47–7.50 (m, 1H, Ar H). ^{13}C NMR ($CDCl_3$) δ 21.07, 21.45, 25.20, 32.04, 32.18, 80.54, 116.71, 116.98, 121.42, 126.43, 128.18, 129.48, 129.80, and 151.11. EIMS *m/z* (%): 458 (M–2SH, 48), 414 (48), 388 (52), 373 (77), 357 (74), 324 (48), 282 (63), 226 (100), 207 (77), 193 (52), and 119 (52).

2H-[1,2,3,4]tetrathiino [5,6-c]spirochromene-2,1´-cyclohexane (8a). Prepared from **2a**. Yellowish green oil, yield 16%. Anal. Calcd for $C_{14}H_{14}OS_4$ (326.51): C 51.50, H 4.32, S 39.28. Found: C 51.31, H 4.29, S 38.99. IR (*v*, cm^{-1}): 2935, 2858, 1268, 1250, 1135, and 775. ^{1}H NMR ($CDCl_3$) δ 1.29–1.85 (m, 10H, 2-cyclohexyl H), 6.98– 7.02 (m, 2H, Ar H), 7.20–7.35 (m, 1H, Ar H), and 7.48– 7.52 (m, 1H, Ar H). ^{13}C NMR ($CDCl_3$) δ 21.29, 21.45, 25.03, 32.18, 35.28, 80.76, 116.98, 117.04, 121.42, 121.60, 121.68, 125.26, 137.80, and 151.22. EIMS *m/z* (%): 326 (M, 10), 294 (23), 230 (16), 198 (13), and 120 (100).

2H, 10H-[1,2,5,6]tetrathiocino[3,4-c:7,8-c´]bis-2,2-dimethylchromene (7b). Prepared from **2b**. Orange oil, yield 33%. Anal.calcd for $C_{22}H_{20}O_2S_4$ (444.64): C 59.42, H 4.53, S 28.84. Found: C 59.03, H 4.48, S 28.53. ^{1}H NMR ($CDCl_3$) δ 1.58 (s, 12H, 4 CH_3), 6.94–6.98 (m, 2H, Ar H), 7.20–7.30 (m, 5H, Ar H), and 7.47–7.50 (m, 1H, Ar H). ^{13}C NMR ($CDCl_3$) δ 22.51, 80.54, 116.70, 116.98, 121.42, 126.44, 128.18, 129.44, 129.80, and 151.21. EIMS *m/z* (%): 378 (M–2SH, 42), 334 (35), 308 (50), 296 (50), 277 (32), 244 (48), and 155 (100).

2H-[1,2,3,4]tetrathiino[5,6-c]-2,2-dimethylchromene (8b). Prepared from **2b**. Colorless oil, yield 5%. Anal. Calcd for $C_{11}H_{10}OS_4$ (286.45): C 46.12, H 3.52, S 44.77, Found: C 45.87, H 3.48, S 44.45. ^{1}H NMR ($CDCl_3$) δ 1.65 (s, 6H, 2 CH_3), 6.99–7.09 (m, 2H, Ar H), 7.20–7.32 (m, 1H, Ar H), and 7.49–7.52 (m, 1H, Ar H). ^{13}C NMR ($CDCl_3$) δ 22.49, 80.76, 116.97, 117.05, 121.42, 121.61, 121.69, 125.26, 137.88, and 151.23. EIMS *m/z* (%): 286 (M, 5), 254 (20), 190 (16), and 149 (100).

Treatment of tetrathiocine 7a with SO_2Cl_2. To a solution of tetrathiocine **7a** (1 g, 2 mmol) in CCl_4 (10 ml), SO_2Cl_2 (2 ml in 5 ml CCl_4) was added dropwise. The solution was stirred at room temperature for 10h, and solvent evaporated under vacuum at room temperature. The crude product was chromatographed on a silica gel column with diethyl ether : n-hexane (1:20) as an eluent to obtain the products (presented in order of their elution).

3,4-Dichloro-3,4-dichlorosulfenyl spirochromane-2,1´-cyclohexane (12). Yellow oil, yield 19%. Anal. Calcd for $C_{14}H_{14}Cl_4OS_2$ (404.20): C 41.59, H 3.49, Cl 35.09, S 15.86. Found: C 41.39, H 3.38, Cl 34.65, S 15.55. ^{1}H NMR ($CDCl_3$) δ 1.23–2.22 (m, 10H, cyclohexyl H), 6.81–6.99 (m, 2H, Ar H), 7.39–7.47 (m, 1H, Ar H), and 7.65–7.85 (m, 1H, Ar H). ^{13}C NMR ($CDCl_3$) δ 21.62, 21.83, 25.11, 27.82, 31.85, 87.79, 92.14, 95.23, 118.00, 119.21, 122.32, 128.73, 136.92, and 156.85. EIMS *m/z* (%): 410 (M^+ Cl^{35}, $3Cl^{37}$, 1), 408 [(M^+ $2Cl^{35}$, $2Cl^{37}$, 4), 406 (M^+ $3Cl^{35}$, Cl^{37}, 16), 404 (M^+ $4Cl^{35}$, 12), 340 (14), 303 (24), 269 (24), 233 (10), 199 (14), and 64 (100).

2H-3,4-dichlorosulfenyl spirochromene-2,1´-cyclohexane (13). Yellow oil, yield 23%. Anal. Calcd for $C_{14}H_{14}Cl_2OS_2$ (333.28): C 50.45, H 4.23, Cl 21.27, S 19.24. Found: C 50.19, H 4.18, Cl 20.92, S 18.95. ^{1}H NMR ($CDCl_3$) δ 1.25–2.23 (m, 10H, cyclohexyl H), 6.82–6.99 (m, 2H, Ar H), 7.39–7.47 (m, 1H, Ar H), and 7.66–7.85 (m, 1H, Ar H). ^{13}C NMR ($CDCl_3$) δ 21.62, 21.82 25.15, 27.82, 31.85, 87.90, 113.16, 114.21, 117.90, 118.97, 122.32, 128.74, 136.93, and 156.91. EIMS *m/z* (%): 300 (M – Cl, Cl^{37}, 1), 298 (M – Cl, Cl^{35}, 4), 269 (2), 263 (6), 198 (10), 155 (15), 121 (100), 92 (73), and 64 (40).

4. Conclusion

The unprecedented 4-oxochromane phosphoro (dithioperoxo)thioic chlorides (**5**) were obtained from 2,2-disubstituted 3-chloro-4-oxochromane-3-sulfenyl chlorides (**2**) with Lawsson's reagent (**3**). **2** reacted with phosphorus pentasulfide to give 1,2,5,6-tetrathiocines (**7**) in addition to 1,2,3,4-tetrathiins (**8**). However, 1,2-dichloro-1,2-disulfenyl chloride (**12**) in addition to 1,2-disulfenyl chloride (**13**) were obtained *via* chlorination of 1,2,5,6-tetrathiocine (**7a**).

5. References

1. C. D. Gabbutt, J. D. Hepworth, B. M. Heron, M. Kanjia, *Tetrahedron* **1994**, *50*, 827–834.
2. K. Oka, S. Hara, *Tetrahedron Lett*. **1977**, 695–698.
3. M. I. Hegab, F. M. E. Abdel-Megeid, F. A. Gad, S. A. Shiba, I. Søtofte, J. Møller, A. Senning, *Acta Chem. Scand*. **1999,** *53,* 284–290.
4. M. I. Hegab, F. A. G. El-Essawy, J. Øgaard, I. Søtofte, A. Senning, *Sulfur Lett*. **2001,** *24*, 191–196.
5. M. I. Hegab, F. M. E. Abdel-Megeid, F. A. Gad, S. A. Shiba, I. Søtofte, J. Møller, A. Senning,. *Acta Chem. Scand*. **1999,** *53*, 133–140.
6. K. Oka, A. Dobashi, S. Hara, *Tetrahedron Lett*. **1980**, 3579–3582.
7. M. I. Hegab, A. A. Amr, F. M. E. Abdel-Megeid, *Z. Naturforsch*. **2002,** *57b*, 922–927.
8. M. I. Hegab, N. A. Hassan, E. M. El-Telbani, I. S. Ahmed Farag, F. M. E.Abdel-Megeid, *Heteroatom. Chem*. **2003,** *14,* 223–228.
9. I. A. Abu-Usef, D. N. Harpp, *Sulfur reports* **2003,** *24*, 255.

10. S. T. A. Shah, K. M. Khan, M. Fecker, W. Voelter, *Tetrahedron Lett*. **2003,** *44,* 6789–6791.
11. S. B. Nielsen, A. Senning, *Tetrahedron Lett*. **1993**, *34,* 2973–2974.
12. H. J. Kabbe, *Synthesis* **1978**, 886–887.
13. F. A. G. El-Essawy, S. M.Yassin, I. A. El-Sakka, A. F. Khattab, I. Søtofte, J. Møller, A. Senning, *J. Org. Chem*. **1998,** *63*, 9840–9845.

Povzetek

V prispevku je predstavljena reakcija 2,2-disubstituiranih 3-kloro-4-oksokroman-3-sulfenil kloridov (**2**) z Lawessonovim reagentom (**3**), pri čemer presenetljivo nastanejo 4-oksokroman fosforo(ditioperokso)tio kloridi (**5**) in ne -tiookso sulfenil kloridi (**6**). Nasprotno pa 2 reagira s fosforjevim pentasulfidom in tvori 1,2,5,6-tetratiocine (**7**) in 1,2,3,4-tetratiine (**8**). Pri nadalnjem kloriranju 1,2,5,6-tetratiocina (**7a**) nastaneta 1,2-dikloro-1,2-disulfenil klorid (**12**) in 1,2-disulfenil klorid (**13**).