Chemistry of Heterocyclic Compounds, Vol. 38, No. 1, 2002

5,7-DICHLORO-1,3-DITHIOLO-[4,5-*d*]PYRIMIDINE-2-THIONE AND -2-SELONE: SYNTHESIS, CRYSTAL STRUCTURE, SOLVATOCHROMISM, AND REACTIONS WITH NUCLEOPHILES*

O. Neilands[1], R. Valters[1], and S. V. Belyakov[2]

We have obtained for the first time the halo derivatives of a novel heterocyclic system, 1,3-dithiolo-[4,5-d]pyrimidine-2-thione and -2-selone, by reaction of 5,7-dioxo(4H,6H)-1,3-dithiolo[4,5-d]-pyrimidine-2-thione and -2-selone with $POCl_3$. The crystal structure of thione confirms that we had obtained the desired compound. The electronic absorption spectra reveal an interesting solvatochromism connected with the appearance of low-intensity n→π transitions from selenium and sulfur atoms in the visible region of the spectrum. The chlorine atoms in the studied compounds have significant mobility in reactions with nucleophiles (amines, thiourea, azidione), which ensures that new derivatives of 1,3-dithiolo[4,5-d]pyrimidine-2-selone are obtained, and specifically 7-N,N-dialkylamino, 7-N-alkyl-N-arylamino derivatives and 7-isothiuronium salts. The 2-selones obtained can be used in synthesis of new tetrathiafulvalenes.

Keywords: 1,3-dithiolo[4,5-*d*]pyrimidines, crystal structure, nucleophilic substitution in chloropyrimidines, solvatochromism of thiones and selones.

Tetrathiafulvalenes (TTF) are basic components for obtaining organic metals and superconductors [1, 2]. Tetrathiafulvalenes condensed with nitrogen-containing heterocycles, especially pyrimidines, have not been widely studied. Dioxopyrimido- and aminooxopyrimido-annelated TTFs **1-3** (Scheme 1), which can form intermolecular complementary hydrogen bonds, are of interest [3].

The starting materials for synthesis of TTF **1** are thione **4**, or more often selone **5** [3-5]. To obtain thiones and selones substituted by different functional groups, the key compounds may be 5,7-dichloro-1,3-dithiolo[4,5-*d*]pyrimidine-2-thione (**6**) and selone **7**. Such compounds had not been described before the research done by our group. The familiar route for conversion of dioxopyrimidines to dichloropyrimidines proved to be successful, namely treatment of thione **4** or selone **5** with phosphorus oxychloride $POCl_3$ in the presence of N,N-diethylaniline at 120°C-125°C. The yield of chromatographically pure orange compound **6** and dark green compound **7** is 55%-75%. When the reaction is carried out under harsher conditions (125°C, 3 h) in the presence of N,N-dimethylaniline, we could chromatographically isolate two compounds: selone **7** and a red-

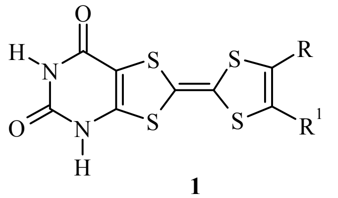
---

* This paper is dedicated to Mikhail Grigorievich Voronkov on his 80th birthday.

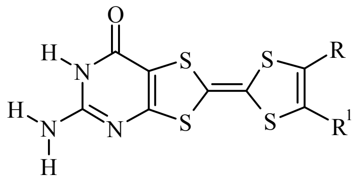
---

[1] Riga Technical University, Riga LV-1048, Latvia; e-mail: neilands@ktf.rtu.lv. [2] Latvian Institute of Organic Synthesis, Riga LV-1006; e-mail: serg@osi.lv. Translated from Khimiya Geterotsiklicheskikh Soedinenii, No. 1, pp. 87-94, January, 2002. Original article submitted June 19, 2001.

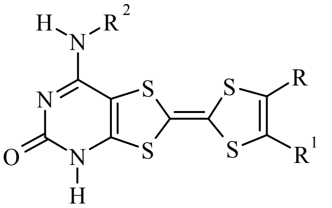
orange product that, based on ^{1}H NMR, electronic spectra, and elemental analysis, was assigned the structure of the product of substitution of chlorine atom: 5-chloro-7-N-methyl-N-phenylamino-1,3-dithiolo[4,5-*d*]-pyrimidine-2-selone (**8**). Such a product could be obtained by reaction of selone **7** with N-methylaniline.



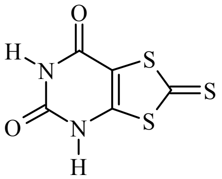
1



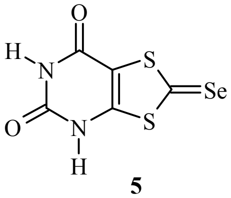
2



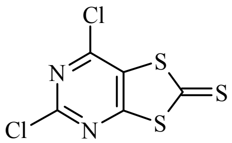
3



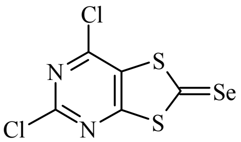
4



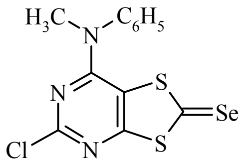
5



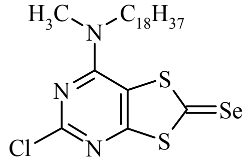
6



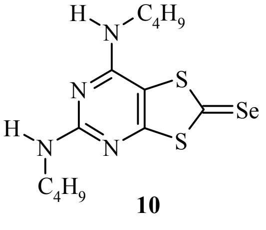
7



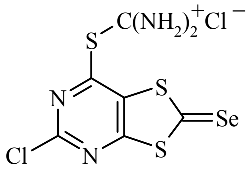
8



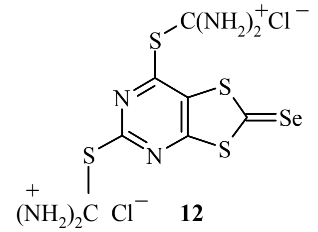
9



10



11



12

Sometimes during crystallization of selone **7**, we observed formation of two types of crystals: dark green and dark red. The latter gradually transformed to dark green ones during storage. Probably here two phases of crystalline selone are formed, of which the dark green form is more stable. This phenomenon was not investigated in more detail. The color of the compounds obtained proved to be nontrivial: it is not typical of the usual 1,3-dithiol-2-thiones (yellow) and 1,3-dithiol-2-selones (orange-red). Accordingly, we took the electronic absorption spectra of thione **6** and selone **7** in solvents of different polarities (ethanol, benzene, carbon tetrachloride). The absorption maxima in the visible region of the spectrum and the intensities are presented in Table 1. It is interesting to note that we observed two absorption maxima: one intense maximum, and another of very low intensity. The compounds exhibit solvatochromism: in the polar solvent ethanol, the low-intensity

TABLE 1. Absorption Spectral Characteristics of 1,3-Dithiolo[4,5-*d*]-pyrimidine Derivatives in the Visible Region

Compound	λ_{max}, nm	ε	λ_{max}, nm	ε	λ_{max}, nm	ε
	In ethanol		In benzene		In CCl_4	
6	356 (not observed)	30900	362 447	27900 70	358 (not measured)	26400
7	392 546	21200 240	400 551	20900 250	391 556	21000 260
8			419 523	(not measured)		
9	426 532	24800 430	429 538	24500 440	426 542	25200 430

maximum is hidden under the intense absorption band. Such solvatochromism is typical of low-intensity *n*→π transitions associated with transfer of an electron from the unshared electron pair of the sulfur or selenium atom to the HOMO of the conjugated pyrimidine system. Owing to the electron-acceptor properties of the chlorine atoms, the energy of the HOMO changes and the *n*→π transition occurs at lower energies compared with the usual thiones and selones.

The structure of thione **6** was confirmed by X-ray diffraction. We were able to grow thione crystals suitable for taking the X-ray patterns and to obtain their diffraction pattern, based on which we calculated the crystal structure. Fig. 1 shows a three-dimensional model of molecule **6** with the designations of the atoms; Fig. 2 illustrates the unit cell of crystals of **6**. Table 2 presents the basic interatomic distances in molecule **6.** We found that molecules of thione **6** are planar within the uncertainty limits and are located practically perpendicular to the glide reflection plane *a*. In the crystal structure, the molecules form stacks along the crystallographic direction *x*. We observe halfway overlap between adjacent molecules in the stack, where the five-membered ring of one molecule overlaps the six-membered ring of the other. The distance between planes of adjacent molecules is 3.550(14) Å. All the molecules in the crystal are packed parallel to the crystallographic plane $(\bar{2}\ 0\ 3)$. Fig. 3 shows a stereoscopic pair representing stacks of molecules in the crystal. The features of the crystallographic structure of **6** result in the fact that during growth, the crystals form thin needles that are elongated along the crystallographic direction $[\bar{2}\ 0\ 3]$. It is difficult to obtain a high-quality diffraction pattern

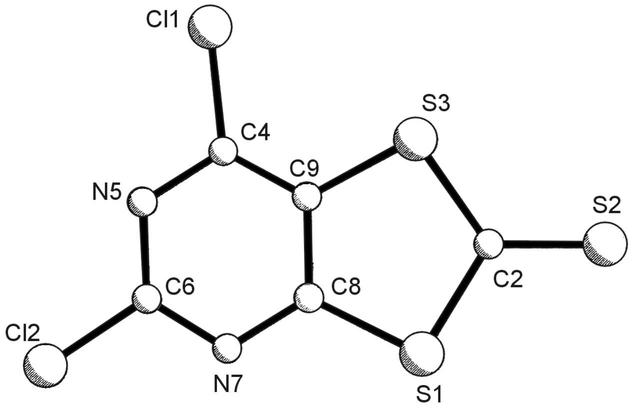


Fig. 1. Structure of thione **6** molecule and the designation of the atoms.

TABLE 2. Bond Lengths in the Molecule of Compound **6**

Bond	Bond length, Å	Bond	Bond length, Å
C(2)–S(1)	1.755(25)	Cl(1)–C(4)	1.717(18)
C(8)–S(1)	1.759(20)	C(6)–N(5)	1.324(31)
S(3)–C(2)	1.737(25)	N(7)–C(6)	1.299(31)
S(2)–C(2)	1.619(25)	Cl(2)–C(6)	1.702(23)
C(9)–S(3)	1.731(19)	C(8)–N(7)	1.343(29)
N(5)–C(4)	1.327(30)	C(9)–C(8)	1.384(25)
C(9)–C(4)	1.331(26)		

from such crystals. This explains the very high value of the *R* factor (11.2%) and the large standard deviations in the geometric parameters. For this reason, detailed discussion of the geometry of the molecule is not quite appropriate.

We studied the reaction of selone **7** with nucleophilic reagents (selone was selected with the aim of synthesizing new derivatives which might be used to obtain new pyrimido-TTFs). The first trials with ammonia showed that the reaction proceeded easily; the chlorine atoms were quite mobile. However, in this case, we were unable to isolate the reaction product in pure form. Reaction of selone **7** with N-methyloctadecylamine proved to be more successful. In fact, in this reaction a novel product is formed which, after chromatographic purification, was assigned the structure of 5-chloro-7-N-methyl-N-octadecylamino-1,3-dithiolo[4,5-*d*]-pyrimidine-2-selone (**9**) based on ^{1}H NMR and electronic absorption spectra and also elemental analysis data. Most likely, in this compound the chlorine atom in the position 7 is more mobile than in the position 5.

Quite contradictory data are given in the literature on nucleophilic substitution of 2,4-dichloropyrimidine [6]. From the experimental section of [6] follows that on reaction of 2,4-dichloropyrimidine with ammonia in ethanol, after the procedure for separation of the mixture, about 10% of 2-amino-4-chloropyrimidine and 30% of 4-amino-2-chloropyrimidine were isolated.

In our case, the chlorine atom in the position 7 of selone **7** can be activated more than the atom in the position 5 due to the adjacent electron-acceptor dithiolselone group. When selone **7** was treated with N-methylaniline in the presence of triethylamine, the reaction product proved to be the mentioned red compound **8**, the spectrum of which in the visible region resembles the spectra of other selones (Table 1), but the intense absorption maximum is shifted to longer wavelengths.

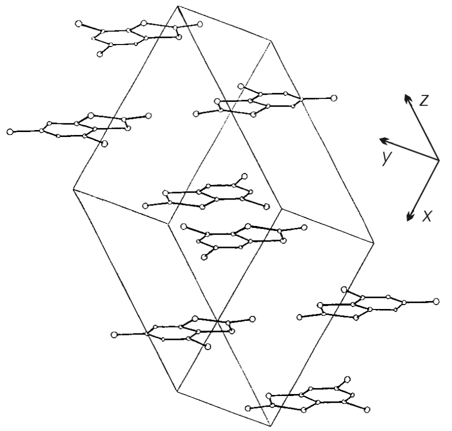


Fig. 2. Arrangement of molecules in the unit cell of crystals of thione **6**.

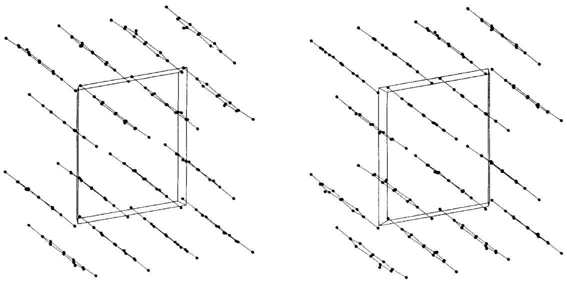


Fig. 3. Stereoscopic representation of the crystal structure along the *y* axis.

The reaction of selone **7** with butylamine in DMF is vigorous, with heating up of the mixture, but we could not isolate the desired product (a yellow-brown, poorly soluble product and a foul-smelling dark red oil were formed), so the reaction was conducted with cooling in benzene solution in the presence of triethylamine. But in this case, we could not isolate the desired 5,7-di(butylamino)-1,3-dithiolo[4,5-*d*]pyrimidine-2-selone (**10**) in pure form.

Selone **7** reacts on heating with thiourea in acetonitrile solution; in this case, a red-orange isothiuronium salt insoluble in acetonitrile is isolated, which based on elemental analysis data is assigned the structure of the monosubstituted isothiureido derivative **11.** Reaction with excess thiourea on boiling in acetonitrile did not lead to the disubstituted product, probably due to the insolubility of the monosubstituted product in acetonitrile. The reaction is easily accomplished in DMF: the solution becomes dark red, but we could not isolate the desired disubstituted product **12** in pure form. Possibly cleavage of the isothiuronium salt occurs in DMF when heated. In the literature [7], it is mentioned that monochloropyrimidines and 2,4-dichloropyrimidine react easily with thiourea in ethanol on boiling. The reaction products, depending on the structure of chloropyrimidine, are isothiuronium salts or their cleavage products, mercapto derivatives: 2,4-dichloropyrimidine is converted to 2,4-dithiouracil. In our case, the possibility is offered of converting selone **7** to 5,7-di(thioxo)-(4H,6H)-1,3-dithiolo[4,5-*d*]pyrimidine-2-selone without isolating diisothiuronium salt **12** in pure form.

The result of the facile reaction of selone **7** with sodium azide in acetonitrile on heating is a poorly soluble, brown material that does not melt up to 330°C, the structure of which is under investigation.

TABLE 3. Coordinates of Atoms and Their Equivalent Isotropic Thermal Parameters in the Molecule of Compound **6**

Atom	*x*	*y*	*z*	B_{eq}, Å^2*
S(1)	0.7595(4)	0.4428(5)	0.8621(4)	2.7(7)
C(2)	0.8390(29)	0.2474(32)	0.9199(22)	5.2(10)
S(3)	0.7608(4)	0.0554(5)	0.8592(4)	4.8(7)
C(4)	0.5317(21)	0.0703(23)	0.6906(17)	4.8(10)
N(5)	0.4343(26)	0.1603(29)	0.6212(23)	4.6(9)
C(6)	0.4351(25)	0.3352(29)	0.6237(21)	5.5(10)
N(7)	0.5295(24)	0.4269(27)	0.6901(20)	6.4(10)
C(8)	0.6265(22)	0.3389(25)	0.7637(19)	3.1(10)
C(9)	0.6306(21)	0.1561(22)	0.7618(17)	3.7(10)
S(2)	0.9727(4)	0.2504(5)	1.0229(4)	4.0(8)
Cl(1)	0.5199(4)	-0.1556(5)	0.6800(4)	3.5(8)
Cl(2)	0.3100(4)	0.4521(5)	0.5358(4)	4.3(8)

---

* The values of B_{eq} are determined as one third of the trace of the orthogonalized tensor B_{ij}.

EXPERIMENTAL

The IR spectra were taken on a Specord M-80 apparatus in paraffin oil or hexachlorobutadiene. The ^{1}H NMR spectra were recorded on a Bruker WH-90/DS (90 MHz) spectrometer in $CDCl_3$ or DMSO-d_6, with TMS as the internal standard. The UV and visible spectra were taken on Specord M-40 in the appropriate solvents.

The starting thione **4** and selone **5** were obtained as in [4, 5].

5,7-Dichloro-1,3-dithiolo[4,5-*d*]pyrimidine-2-thione (6). Mixture of freshly distilled phosphorus oxychloride (18 ml) and N,N-diethylaniline (2 ml) was added to thione **4** (0.65 g). With stirring, the temperature was slowly raised up to 90°C and then was raised rapidly up to 120°C. At this temperature, the mixture was stirred for 1 h, cooled, and poured over 50 g of ice. After 15 h, the residue was filtered off, washed with water, dried, and crystallized from hexane. The yield of orange crystals of compound **6** was 0.43 g (55%); mp 134°C. IR spectrum, ν, cm^{-1}: 1512, 1480, 1305, 1280, 1080, 1060, 884, 850, 815. Found, %: Cl 28.50. $C_5Cl_2N_2S_3$. Calculated, %: Cl 27.78.

5,7-Dichloro-1,3-dithiolo[4,5-*d*]pyrimidine-2-selone (7). Mixture of freshly distilled phosphorus oxychloride (36 ml) and N,N-diethylaniline (3.6 ml) was added to selone **5** (2.12 g, 8 mmol). With stirring, the temperature was raised up to 90°C over the course of 1 h, and then was raised rapidly up to 120°C. The mixture was stirred for 3 h at temperature of 120-125°C, then it was cooled and poured over ice (250 g). Green oil was separated which solidified under stirring. The green residue was filtered off, washed with water until it tested neutral, and dried in air. The dry product was dissolved with boiling in benzene (200 ml). The red solution was passed through a column with silica gel; the red eluate was completely evaporated down in a rotary evaporator. The oily residue was crystallized. The yield of dark green, shiny crystals of compound **7** was 1.85 g (76%); mp 118-120°C. On crystallization from a moderate amount of benzene, along with the green crystals sometimes orange-red crystals formed, which on storage transformed to dark green crystals. The material can be recrystallized from absolute ethanol. Crystallization is not needed for further nucleophilic substitution reactions. IR spectrum, ν, cm^{-1}: 1512, 1490, 1306, 1274, 1212, 982, 956, 892, 860, 826. Found, %: Cl 23.05; S 20.80. $C_5Cl_2N_2S_2Se$. Calculated, %: Cl 23.47; S 21.23.

5-Chloro-7-(N-methyl-N-phenyl)amino-1,3-dithiolo[4,5-*d*]pyrimidine-2-selone (8). A. Phosphorus oxychloride (10 ml) and dimethylaniline (1 ml) were added to selone **5** (0.53 g, 2 mmol). The temperature was raised to 125°C and the mixture was stirred at this temperature for 3 h. After cooling, the reaction mixture was poured into water (200 ml). The precipitate was filtered off, washed with water, dried, and dissolved in benzene, then chromatographed on silica gel (1:1 benzene–hexane as the eluent) and two fractions were collected. After evaporating down the first fraction, 0.18 g (30% yield) of selone **7** were obtained; after evaporating down the second fraction, 0.23 g of red-orange crystals of selone **8** were obtained (31% yield).

B. Dichloroselone **7** (0.15 g, 0.5 mmol) was added to acetonitrile (15 ml) and heated until dissolved. Then mixture of N-methylaniline (0.06 g, 0.56 mmol) and triethylamine (0.06 g, 0.59 mmol) in acetonitrile (5 ml) was added. This was stirred at 50-60°C until the starting selone disappeared. The reaction mixture was evaporated down to dryness, and the residue was dissolved in benzene and chromatographed on silica gel (1:1 benzene–hexane as the eluent). The eluate was evaporated down and the residue was mixed with a moderate amount of hexane. Selone **8** was filtered off; yield 0.1 g (54%). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 3.55 (3H, s, CH_3); 7.28 and 7.55 (5H, m, C_6H_5). Found, %: C 38.35; H 2.03; Cl 9.92; N 10.91; S 17.45. $C_{12}H_8ClN_3S_2Se$. Calculated, %: C 38.67; H 2.16; Cl 9.51; N 11.27; S 17.20.

5-Chloro-7-(N-methyl-N-octadecyl)amino-1,3-dithiolo[4,5-*d*]pyrimidine-2-selone (9). Methyloctadecylamine (0.375 g, 1.32 mmol) was added to solution of selone **7** (0.2 g, 0.65 mmol) in benzene (10 ml) and stirred at room temperature until the starting compound disappeared. The reaction was followed using TLC (silica gel, 1:1 benzene–hexane as the eluent). The reaction took several days. The mixture was separated chromatographically on silica gel. Obtained a red substance, yield 0.2 g (55%). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm: 0.85 t, 1.23 m, 2.5 m ($C_{17}H_{35}$); 3.25 (3H, s, CH_3N); 3.57 (2H, t, CH_2N). Found, %: C 51.95; H 7.21; N 7.56; S 12.05. $C_{24}H_{40}ClN_3S_2Se$. Calculated, %: C 52.49; H 7.34; N 7.65; S 11.68.

5-Chloro-7-isothiuronio-1,3-dithiolo[4,5-*d*]pyrimidine-2-selone Chloride (11). Thiourea (0.05 g, 0.66 mmol) was added to acetonitrile (5 ml) and heated until it dissolved. Selone **7** (0.15 g, 0.5 mmol) was dissolved in acetonitrile (5 ml) with heating; both solutions were combined and boiled for 30 min until the starting selone disappeared. The reaction was followed using TLC (silica gel, 1:1 benzene–hexane as the eluent). An orange-brown residue was formed, which was filtered off and washed with acetonitrile. Yield 0.15 g (80%). The sample did not melt up to 220°C. IR spectrum, ν, cm^{-1}: 3200, 2980, 1690, 1670, 1660, 1640. Found, %: Cl 18.2; S 26.1. $C_6H_4Cl_2N_4S_3Se$. Calculated, %: Cl 18.75; S 25.44.

X-ray Diffraction Analysis. 1363 Diffraction reflections were measured on a Syntex-$P2_1$ automatic four-circle diffractometer using molybdenum radiation (λ 0.71069 Å). Single crystals of compound **6** are assigned to monoclinic syngony, crystal lattice parameters: a = 9.642(3), b = 7.570(3), c = 12.016(4) Å; β = 100.36(3)°; V = 862.7 $Å^3$; D_x = 1.96 $g \cdot cm^{-3}$; μ = 1.38 cm^{-1}; $F(000)$ = 504; space group $P\ 2_1/a$; Z = 4. The structure was solved by the direct method and refined by the least squares method in the full-matrix anisotropic approximation. We used 964 independent reflections with $|F| > 2\sigma_F$ and 109 refined parameters in the calculations. The final value of the R factor was 0.112. The coordinates of the atoms and their equivalent isotropic thermal parameters are given in Table 3. The calculations were performed using the AREN software package [8].

I. Sudmale, I. Lielbriedis, and I. Gudele participated in the experimental work.

REFERENCES

1. M. R. Bryce, *Chem. Soc. Rev.*, **20**, 355 (1991).
2. J. P. Farges (ed.), *Organic Conductors: Fundamentals and Application*, Marcel Dekker, New York (1994).
3. O. Neilands, *Molecular Crystals and Liquid Crystals*, **355**, 331 (2001).
4. O. Ya. Neiland, V. Yu. Khodorkovskii, and V. Zh. Tilika, USSR Inventor's Certificate 1738810, *Byull. Izobret.*, No. 21 (1992).
5. O. Ya. Neiland, V. Yu. Khodorkovskii, and V. Zh. Tilika, *Khim. Geterotsikl. Soedin.*, 1667 (1992).
6. G. E. Hilbert and T. B. Johnson, *J. Am. Chem. Soc.*, **52**, 1152 (1930).
7. M. P. V. Boarland and J. F. M. McOmie, *J. Chem. Soc.*, 1218 (1951).
8. V. I. Andrianov, *Kristallografiya*, **32**, 228 (1987).