

Studies of Thioacids and Their Derivatives

XIV. Reactions of Carbon Disulfide with Active Methylene Compounds

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The reactions of carbon disulfide with several active methylene compounds have been studied, especially with a view to the influence of the solvent and the applied base. The primary products, which are 1,1-dithiolates, have been transformed into *S,S'*-dialkyl derivatives (Table 2), dithiolans (Table 3), dithians (Table 4), and dithiolan and dithian derivatives (Table 5).

Dithiolates of the type $\text{XYC}=\text{C}(\text{SNa})_2$ give a mixture of *cis-trans*-isomeric dithiolanols or dithiolanones, but these are easily interconvertible and could not be separated. A dithiolanone derived from ethyl cyanoacetate may be rearranged into two thiophen derivatives.

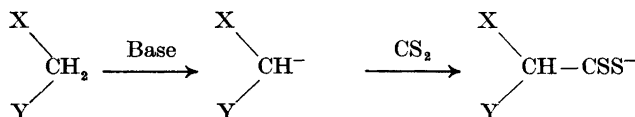
Depending upon the reaction conditions, propargyl bromide may react with a dithiolate to form either a methylthiole or a methylene-dithiolan. The constitution of these products was proved by NMR spectroscopy.

Preparatory to studies on the reaction of carbon diselenide with organic compounds containing reactive methylene groups we have studied the analogous reactions with carbon disulfide, partly to become acquainted with this type of reaction using a more easily accessible substance than carbon diselenide and partly to extend the available material.

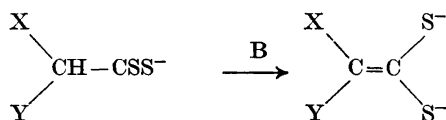
Early attempts to prepare well-defined compounds from the reactions of carbon disulfide with active methylene compounds (ethyl acetoacetate, diethyl malonate, acetophenone, *etc.*) encountered great difficulties, and it is only in more recent times that these reactions have been studied more extensively. The reactions with ethyl acetoacetate were cleared up by Laakso¹ and those with diethyl malonate and other derivatives of malonic acid (ethyl cyanoacetate, malononitrile) by Söderbäck² and by Gompper and Töpfl.³ The reactions of ketones with carbon disulfide have been studied very carefully by Thuillier and Vialle.⁴ Other compounds studied are nitromethane⁵ and 1-phenyl-3-methyl-5-pyrazolone.⁶ The NH_2 group of cyanamide reacts in a similar way as a reactive methylene group.⁷ We have studied the reactions

of compounds of all these types and in addition barbituric acid, with carbon disulfide, as well as the formation of heterocyclic compounds from the resulting 1,1-dithiolates.

Although there is no direct proof of the mechanism of reaction of carbon disulfide with active methylene compounds, there can be little doubt that the reaction proceeds *via* a carbanion (as was also assumed by Gompper and Töpfl³):



When the acidity of the remaining hydrogen atom is not high enough — or when there is none — the reaction may stop at this stage, the formation of a dithiocarboxylate,^{1,7} but more often the second proton is also split off by the base with the formation of the dianion of a 1,1-dithiol:



If a sufficiently strong base is employed even very weakly acidic methylene compounds, such as diphenylmethane, can be induced to react with carbon disulfide. However, very weakly basic carbanions are unreactive. Thus, we were unable to induce a reaction between cyanoform or nitroform and carbon disulfide.

Whether a solvent having itself acid character can be used depends upon the acidity of the methylene compound and the relative reactivity of the carbanion and the anion formed from the solvent. Cyanamide, ethyl cyanoacetate, and malononitrile react well with carbon disulfide in alcoholic solution, but diethyl malonate did not react with carbon disulfide and sodium ethoxide in ethanolic solution: only the xanthate could be isolated. However, diethyl malonate reacts with carbon disulfide and sodium ethoxide in ether solution, and we have found that the reaction can be carried out very conveniently in this and similar cases by addition of solid potassium hydroxide to a solution of carbon disulfide and the methylene compound in ether-dioxane. This method fails with very weakly acidic methylene compounds, such as ketones, but as shown by Thuillier and Vialle⁴ these can be transformed into dithiolates in benzene solution, using sodium 2-methyl-2-butanolate as the base. The salts were usually employed for further reactions after filtering and washing with ether. They are hygroscopic and difficult to purify. Söderbäck² has prepared some salts of this kind in the form of hydrates and this was confirmed in this investigation in which some additional salts were prepared in a pure or approximately pure state. The known salts are listed in Table 1.

In many cases it was found advantageous to carry out a reaction without isolation of the dithiolate. Dimethylformamide and dimethyl sulfoxide were

Table 1. Dithiolates prepared from active methylene compounds and carbon disulfide.

Methylene compound	Formula of reaction product	Dithi- olate No.	Solvent used for prepara- tion	Base	Yield, %
Dimethyl malonate	$(\text{NaS})_2\text{C}=\text{C}(\text{CO}_2\text{CH}_3)_2$	1	methanol	NaOMe	40-46
Diethyl malonate	$(\text{KS})_2\text{C}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2^a$	2	ether-dioxan	KOH	90
»	»		dioxan	KOH	87
Methyl cyanoacetate	$(\text{NaS})_2\text{C}=\text{C}(\text{CN})\text{CO}_2\text{CH}_3 \cdot 5\text{H}_2\text{O}$	3	methanol	NaOMe	60-87
Ethyl cyanoacetate	$(\text{NaS})_2\text{C}=\text{C}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5 \cdot 5\text{H}_2\text{O}$	4	ethanol	NaOEt	78-87
»	»	5	ether-dioxan	KOH	67
»	»		dioxan	KOH	91
Malononitrile	$(\text{NaS})_2\text{C}=\text{C}(\text{CN})_2 \cdot 3\text{H}_2\text{O}$	6	ethanol	NaOEt	82-96
»	$(\text{KS})_2\text{C}=\text{C}(\text{CN})_2 \cdot \text{H}_2\text{O}^a$	7	dioxan	KOH	91
Cyanamide	$(\text{KS})_2\text{C}=\text{N}-\text{CN}$	8	ethanol	KOH	61
»	»		water	KOH	90
»	»		ethanol	KOEt	69-78
Calcium cyanamide	$(\text{KS})_2\text{C}=\text{N}-\text{CN}$		water	(K_2CO_3)	70
Barbituric acid	$\text{C}_5\text{HN}_3\text{N}_2\text{O}_3 \cdot 8\text{H}_2\text{O}^a$	9	water	NaOH	70

^a New compounds.

found to be well-suited solvents in these cases, and when sodium 2-methyl-2-butanolate was used as the base all compounds with a reactive methylene group could be induced to react. These solvents are not suitable, however, when it is intended to isolate the salts.

The free acids are unstable and only in a few cases, such as 5-hydroxy-3-methyl-1-phenylpyrazole-4-carbodithioic acid, has it been possible to isolate them in a pure state. The available evidence, including our own potentiometric titrations, indicates that the acids are normally strong acids ($\text{p}K_1 \sim 0$) with respect to the first dissociable hydrogen atom, whereas the second ionization constant is rather variable ($\text{p}K_2 \sim 5.5-10$). Since they are strong acids, it is not possible to estimate $\text{p}K_1$ (as was done in Ref. 4) from pH of a half neutralized solution.

The discussion of the strength of these acids is complicated by the possibility that a substituent might exert its influence either directly or by displacing the tautomeric equilibrium. The only existing experimental data which seem to be relevant to the discussion of the tautomeric equilibrium between a dithiocarboxylic acid and a dithiol are the iodometric titrations of 1,1-dithiomalonic esters by Laakso,¹ which indicate that enethiolization is diminished by introduction of a methyl group in the α -position. It is hoped to get more definite information about the extent to which the various dithio acids exist in the dithiocarboxylic and the dithiol form by infrared and NMR spectroscopic studies.

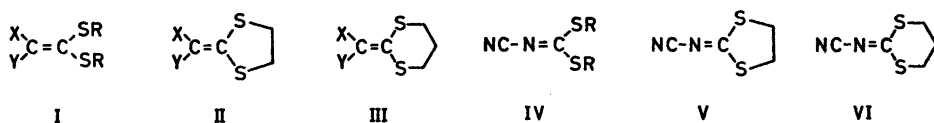
COMPOUNDS DERIVED FROM THE 1,1-DITHIOLS

The dithiolates react readily with alkyl halides to form bis(alkylthio) derivatives (I and IV), and with 1,2-dibromoethane or 1,3-dibromopropane to form dithiolans (II and V) or dithians (III and VI).

Table 2. *S,S'*-Dialkyl derivatives of ethylene-1,1-dithiols.

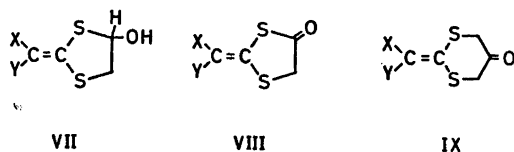
Formula	Yield, %	M.p., °C	Solvent used for recrystal.	Analyses
$(\text{CH}_3)_2\text{C}=\text{C}(\text{CO}_2\text{CH}_3)_2$, ^{2,3} $(\text{C}_6\text{H}_5\text{CH}_2)_2\text{C}=\text{C}(\text{CO}_2\text{CH}_3)_2$	42 ^a 34 ^a	77 — 78 56 — 57	benzene ether	Found: C 62.00; H 5.40 Calc.: C 61.83; H 5.19
$(\text{CH}_3)_2\text{C}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2$ ¹	—	12 — 15 b.p. 193 — 195/12 mm	ether-petroleum ether	Found: C 45.37; H 6.05; S 24.14 Calc.: C 45.43; H 6.09; S 24.26
$(\text{C}_6\text{H}_5\text{CH}_2)_2\text{C}=\text{C}(\text{CO}_2\text{C}_2\text{H}_5)_2$	55 ^a 63 ^b	32 — 35	methanol and ether	Found: C 63.20; H 5.66; S 15.15 Calc.: C 63.43; H 5.81; S 15.39
$(\text{CH}_3)_2\text{C}=\text{C}(\text{CN})\text{CO}_2\text{CH}_3$, ^{2,3} $(\text{HO}_2\text{C}-\text{CH}_2)_2\text{C}=\text{C}(\text{CN})\text{CO}_2\text{CH}_3$	91 ^b 68 ^b	86 — 86.5 157 — 158	methanol and ether ethanol-water	Found: C 37.38; H 3.32; N 4.74 Calc.: C 37.11; H 3.13; N 4.81
$(\text{CH}_3)_2\text{C}=\text{C}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$	83 — 96 ^b	58.5 — 59 52.5 — 53	ether; low melting form from ether-pentane and methanol	Found: C 44.27; H 5.29; N 6.35; S 29.54 Calc.: C 44.22; H 5.11; N 6.44; S 29.50
$(\text{C}_6\text{H}_5\text{CH}_2)_2\text{C}=\text{C}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$	79 ^b	85 — 86	ether	Found: C 64.70; H 5.30; N 3.65; S 17.35 Calc.: C 64.97; H 5.19; N 3.79; S 17.35
$(p\text{-NO}_2\text{C}_6\text{H}_4\text{CH}_2)_2\text{C}=\text{C}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$	86 ^b	145 — 146	ether-methanol	Found: C 52.10; H 3.72; N 8.09; S 14.17 Calc.: C 52.28; H 3.72; N 8.14; S 13.95
$(\text{HO}_2\text{C}-\text{CH}_2)_2\text{C}=\text{C}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$	95 ^b	163 — 165	methanol-water	Found: C 39.36; H 3.70; N 4.73; S 20.96 Calc.: C 39.35; H 3.64; N 4.59; S 21.00
$(\text{CH}_3)_2\text{C}=\text{C}(\text{CN})\text{CO}_2\text{C}_2\text{H}_5$	55 ^b	40.5 — 41	ether	Found: C 43.51; H 4.63; N 4.28; S 19.35 Calc.: C 43.24; H 4.53; N 4.20; S 19.24
$(\text{CH}_3)_2\text{C}=\text{C}(\text{CN})_2$, ^{2,3}	95 ^b	82.4 — 83	ether and methanol	Found: C 67.20; H 4.44; N 8.73 Calc.: C 67.02; H 4.37; N 8.69
$(\text{C}_6\text{H}_5\text{CH}_2)_2\text{C}=\text{C}(\text{CN})_2$	69 ^b	83 — 84	ether-chloroform	Found: C 64.85; H 5.47 Calc.: C 64.40; H 4.73
$(\text{CH}_3)_2\text{C}=\text{N}-\text{CN}$ ⁶ $(\text{C}_6\text{H}_5\text{CH}_2)_2\text{C}=\text{N}-\text{CN}$ ¹²	76 ^b 70 ^b	53 — 54.5 82 — 83	methanol-water pentane-methanol	Found: C 28.67; H 3.27; N 10.38 Calc.: C 28.58; H 3.20; N 11.10
$(\text{HO}_2\text{C}-\text{CH}_2)_2\text{C}=\text{N}-\text{C}-\text{NH}_2\text{O}$	—	122 — 123	water	
$(\text{CH}_3)_2\text{C}=\text{CHCO}_2\text{C}_2\text{H}_5$ ¹	42 ^d	53 — 55.5	ether	Found: C 50.80; H 4.30; N 8.84 Calc.: C 50.64; H 3.93; N 9.09
$\text{HO}_2\text{C}-\text{CH}_2\text{S}-\text{C} \begin{array}{c} \text{H}_3\text{C} \\ \diagup \\ \text{N} \\ \diagdown \\ \text{S} \\ \text{OH} \end{array} \text{N}-\text{C}_6\text{H}_5$	15 ^c	168 — 169	ethanol	

^a Yields based on the methylene compound. ^b Yields based on the sodium or potassium dithiolate. ^c Yields based on the dithiocarbonylic acid. ^d From ethyl acetoacetate with sodium methanolate in DMF.

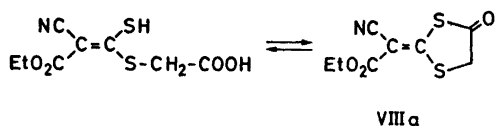


Several new compounds of these classes have been listed in Tables 2—4. By varying the reaction conditions, it was often possible to improve the yields of known compounds.

1,3-Dithiolan-4-ols (VII), 1,3-dithiolan-4-ones (VIII), and 1,3-dithian-5-ones (IX) have been prepared by reaction of dithiolates with chloroacetaldehyde, bromoacetic acid, and 1,3-dichloroacetone, respectively. Compounds of these types were hitherto unknown, but after the conclusion of our investigation Gompper and Schaefer⁸ have described a dithiolanone obtained from the reaction of chloroacetamide with the dithiolate prepared from benzyl cyanide. Further, Campaigne and Haaf⁹ have described some 1,3-dithiolan-4-ols obtained from dithiolates and α -haloketones.



The reaction of the dithiolate prepared from ethyl cyanoacetate with one mole of a haloacetic acid results in the formation of ethyl 4-oxo-1,3-dithiolan-2-ylidenecyanoacetate. This compound is soluble in alkali and it could be shown that this is not due to enolization but to ring-opening, so that the cyclization is a reversible process:



Potentiometric titrations of this dithiolanone in 50 % ethanol show that it functions as a divalent acid with $\text{p}K_1 \sim 0$ and $\text{p}K_2 = 5.4$. However, the base consumption during neutralization of the second acidic group was only 80—85 % of the amount used in the first step, whereas on dissolution of the dithiolanone in aqueous 0.1 N NaOH and back-titration the theoretical values were found for both steps. The reason is that the ring-opening in alcohols is accompanied, to some extent, with ester formation:

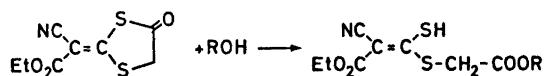



Table 3. Derivatives of 1,3-dithiolans  C-R, prepared from dithiolates and 1,2-dibromoethane.

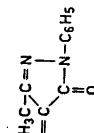
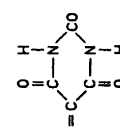
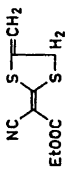
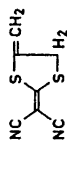
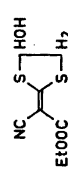

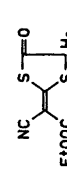
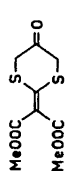
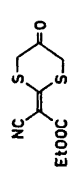
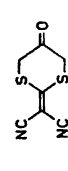
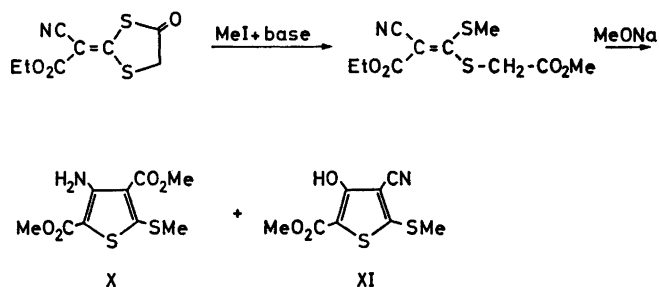
R	Prepared from	Formula	Solvent used in the reaction	Yield, %	M.p., °C	Solvent used for recrystal.	Analyses
$=C(CO_2CH_3)_2$	dimethyl malonate	$C_8H_{10}O_4S_2$	dimethylformamide ^a	68-84	72-73	heptane and methanol	Found: C 41.30; H 4.54 Calc.: C 41.01; H 4.30
$=C(CO_2C_2H_5)_2$	diethyl malonate	$C_{10}H_{14}O_4S_2$	ethanol ^b	46-51	59-60	ether.	Found: C 45.83; H 5.13; S 24.34 Calc.: C 45.80; H 5.38; S 24.81
$=C(CN)CO_2CH_3$ ³	methyl cyanoacetate	$C_7H_7NO_2S_2$	methanol ^a 1,2-ethanediol ^b dimethylformamide ^b	57-70	147-148	pentane methylene chloride	
$=C(CN)CO_2C_2H_5$	ethyl cyanoacetate	$C_9H_9NO_2S_2$	ethanol ^a ethanol-water (1:1) ^b	88-98	105-106	methanol and ether-methylene chloride	Found: C 44.76; H 4.19; N 6.72; S 29.87 Calc.: C 44.66; H 4.23; N 6.51; S 29.78
$=C(CN)_2$ ³	malonitrile	$C_6H_8N_2S_2$	ethanol ^a 1,2-ethanediol ^b	46-95	203-204	methylene chloride	
$=C(COCH_3)CO_2C_2H_5$	ethyl acetoacetate	$C_9H_{12}O_3S_2$	dimethylformamide ^a	60-73	81.5-82	methanol and ether	Found: C 46.78; H 5.08; S 27.34 Calc.: C 46.52; H 5.21; S 27.60
$=C(CN)C_6H_5$	benzyl cyanide	$C_{11}H_9NS_2$	dimethylformamide ^a	69	51-52	ether	Found: C 60.15; H 4.08; N 6.38; S 29.02 Calc.: C 60.30; H 4.11; N 6.39; S 29.24
$=CH(COC_6H_5)_2$ ^{4,13}	aceto-phenone	$C_{11}H_{10}OS_2$	methanol-water (3:1) ^a dimethylformamide ^a	72	82-83	methanol	Found: C 59.45; H 4.44; S 29.10 Calc.: C 59.42; H 4.54; S 28.83
$=CH(COCH_3)_2$ ⁴	acetone	$C_8H_8OS_2$	dimethylformamide ^a	80			
$=N-CN$	cyanamide	$C_4H_4N_2S_2$	dimethylformamide ^a 1,2-ethanediol ^b dimethylformamide ^b	46 43 65	74-75 79-79.5	ether toluene-heptane	Found: C 33.53; H 2.66; N 19.28 Calc.: C 33.35; H 2.78; N 19.45
	3-methyl-1-phenyl-5-pyrazolone	$C_{13}H_{12}N_2OS_2$	acetone-water (1:1) ^b	70	166-167	methanol	Found: C 56.90; H 4.59; N 10.19; S 23.14 Calc.: C 56.52; H 4.52; N 10.14; S 23.16
	barbituric acid	$C_4H_4N_2O_3S_2$ ^c	ethanol-water (1:1) ^b	46	>340	dimethylformamide	Found: C 36.45; H 2.85; N 12.33; S 27.65 Calc.: C 36.54; H 2.63; N 12.18; S 27.88

Table 5. 4- and 5-Substituted 1,3-dithiolans and 1,3-dithians.

Formula	Halogen comp.	Solvent used in the reaction	Yield, %	M.p., °C	Recrystal. from	Analyses
	$C_9H_9NO_3S_2$ propargyl bromide	dimethylformamide	76	139.5–141	toluene and methanol	Found: C 47.46; H 3.82; N 5.92 Calc.: C 47.58; H 3.97; N 6.17
	$C_7H_7N_2S_2$ propargyl bromide	dimethylformamide	67	125–126	toluene-heptane	Found: C 46.60; H 2.28; N 15.12; S 35.23 Calc.: C 46.66; H 2.22; N 15.35; S 35.55
	$C_8H_9NO_3S_2$ chloroacet-aldehyde	water	100	113–117	methanol-water and toluene	Found: C 41.70; H 3.87; N 5.76; S 27.46 Calc.: C 41.57; H 3.96; N 6.06; S 27.71
	$C_6H_7N_2OS_2$ chloroacet-aldehyde	water	55	168–175 (decomp.)	toluene and methanol-water	Found: C 39.30; H 2.45; N 15.00; S 34.88 Calc.: C 39.13; H 2.17; N 15.22; S 34.78
	$C_8H_7NO_3S_2$ bromoacetic acid methyl chloroacetate ethyl bromoacetate	water methanol ethanol	91 80 94	a) 147–153 (decomp.) b) 126–128 (decomp.)	a) formic acid or methanol b) formic acid-hydrochloric acid	Found: C 41.85; H 3.01; N 6.02 Calc.: C 41.93; H 3.08; N 6.13
	$C_9H_{10}O_6S_2$ 1,3-dichloroacetone	water	15	145–146.5	methanol and ethyl acetate	Found: C 41.05; H 3.89 Calc.: C 41.21; H 3.93
	$C_8H_7NO_3S_2$ 1,3-dichloroacetone	water	77–96	152–153	toluene and heptane	Found: C 44.20; H 3.72; N 5.68; S 26.10 Calc.: C 44.42; H 3.73; N 5.75; S 26.35
	$C_7H_7N_2OS_2$ 1,3-dichloroacetone	water	81	150–151	toluene and heptane	Found: C 42.90; H 2.30 Calc.: C 42.80; H 2.42

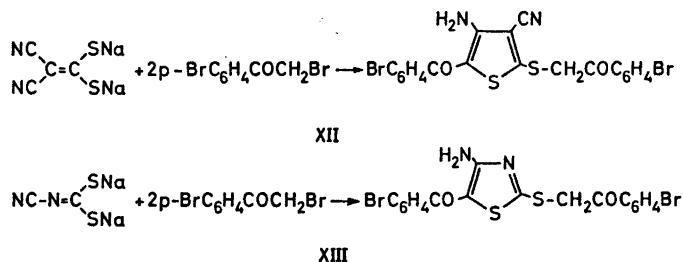
This conclusion was corroborated by employing methanol as solvent, when a compound was obtained ($R = CH_3$) which according to its NMR spectrum contained a methyl group as well as ethyl and methylene groups. This compound could also be prepared from the dithiolate and one mole of methyl chloroacetate.

When VIIIa is treated with methyl iodide and sodium methanolate—or when the dithiolate is treated with one mole of methyl iodide, one mole of methyl chloroacetate, and one mole of sodium methanolate—the S,S' -dialkyl derivatives cyclize to a mixture of an aminothiophen (X) and a hydroxythiophen (XI).



The two reaction products could be separated by treatment with potassium hydroxide, which dissolved only the hydroxythiophen (transesterification occurred during this process). The generality of this type of reaction was shown by the formation of both an aminothiophen and a hydroxythiophen from $(\text{EtO}_2\text{C})(\text{CN})\text{C}=\text{C}(\text{SCH}_2\text{CO}_2\text{Me})_2$. The assigned structures were corroborated by the infrared and NMR spectra of these compounds (Table 6). The formation of aminothiophens has also been observed by Gompper *et al.*¹⁰ in similar reactions.

Ring-closure reactions which involve a nitrile group have also been observed when dithiolate 8 or dithiolate 6 was treated with *p*-bromophenacyl bromide. Instead of an S,S' -bis(bromophenacyl) derivative, an aminothiophen or an aminothiazole is formed:



In the first example the product still contains a nitrile group, according to its infrared spectrum, *i.e.* ring-closure has only taken place with one of the

Table 6. NMR spectra.^a

Compound	Chemical shifts	Assignment	Solvent
VII, X = Y = CN	3.30–4.20, s, 1 H	–OH	(CD ₃) ₂ SO
	3.50, t, <i>J</i> = 2.5, 1 H	–SCH(OH)–	
	5.96, d, <i>J</i> = 2.5, 2 H	–SCH ₂ –	
VII, X = CN, Y = COOEt ^b	2.70, s, 1 H	–OH	(CD ₃) ₂ SO
	3.75, t, <i>J</i> = 2.5, 1 H	–SCH(OH)–	
	6.25, t, <i>J</i> = 2.5, 2 H	–SCH ₂ –	
VIIIa, ^b high-melting form	5.83, s, 2 H	–SCH ₂ –	CDCl ₃
	5.77, s, 2 H	–SCH ₂ –	
VIIIa, ^b low-melting form	5.83, s, 2 H	–SCH ₂ –	CDCl ₃
	5.83, s, 2 H	–SCH ₂ –	
X	3.17, s, 2 H	–NH ₂	CDCl ₃
	6.10, s, 3 H	–OCH ₃	
	6.19, s, 3 H	–OCH ₃	
	7.43, s, 3 H	–SCH ₃	
XI	0.25, s, 1 H	–OH	CDCl ₃
	6.10, s, 3 H	–OCH ₃	
	7.32, s, 3 H	–SCH ₃	
XII	1.97–2.52, m, 10 H	2C ₂ H ₄ + –NH ₂	(CD ₃) ₂ SO
	4.97, s, 2 H	–SCH ₂ –	
XIII	1.92–2.53, m, 10 H	2C ₂ H ₄ + –NH ₂	(CD ₃) ₂ SO
	4.95, s, 2 H	–SCH ₂ –	
XIV ^b	2.93, s, 2 H	–SCH=	CDCl ₃
XV, X = Y = CN	4.17, q, <i>J</i> = ca. 1.5, 1 H	=CH ₂	(CD ₃) ₂ SO
	4.22, q, <i>J</i> = ca. 1.5, 1 H	=CH ₂	
	5.29, t, <i>J</i> = ca. 1.5, 2 H	–SCH ₂ –	
	4.30, q, <i>J</i> = ca. 1.5, 1 H	=CH ₂	
XV, X = CN, Y = COOEt ^b	4.42, q, <i>J</i> = ca. 1.5, 1 H	=CH ₂	(CD ₃) ₂ SO
	5.52, t, <i>J</i> = ca. 1.5, 2 H	–SCH ₂ –	
	3.33, – ^c , 1 H	=CH–	
XVII, X = CN, Y = COOEt ^b	3.33, – ^c , 1 H	=CH–	CDCl ₃
	7.62, – ^c , 3 H	–CH ₃	

^a Recorded at 60 Mc/s with TMS as internal reference. Chemical shifts are in τ values, coupling constants in cps; s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet.

^b In derivatives of ethyl cyanoacetate the signals from the ethyl group were found at 5.69, q, and 8.65, t, in CDCl₃, and at 5.79, q, and 8.75, t, in (CD₃)₂SO.

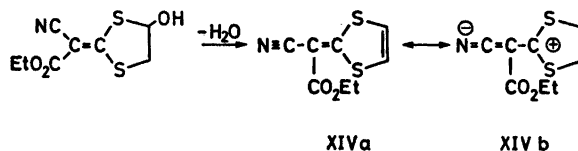
^c These signals were broad (7–8 cps) and showed no definite pattern, probably due to a weak coupling combined with slightly different signals from *cis*- and *trans*-isomer. By recording the spectrum at 100 Mc/s, the signal at 3.33 τ was resolved into two narrow triplets, and the signal at 7.62 τ as a very narrow multiplet. Spin decoupling at low field changed the signal at high field to a singlet, and spin decoupling at high field changed the two triplets into two singlets with a spacing of 2 cps.

nitrile groups. The formulae XII and XIII are also supported by NMR spectra (Table 6).

The yields of 1,3-dithiolan-4-ols (VII) obtained in the reaction between dithiolates and chloroacetaldehyde are very dependent upon the pH of the solution. From dithiolate 4, low yields (< 35 %) were obtained in basic solution, and on addition of a strong acid at most a negligible yield was obtained. On addition of KH₂PO₄ however, the dithiolanol was obtained in almost 100 % yield. When dithiolate 6 was used no dithiolanol was formed

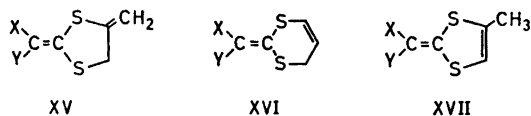
in neutral solution, but it was formed in good yield on addition of hydrochloric acid.

The dithiolanols (VII) are transformed into dithioles on treatment with concentrated sulfuric acid (*cf.* Ref. 9):



The infrared spectrum (see later) of the dithiole indicates that there is some contribution from the dithiolylium resonance structure (XIVb).

A cyclic product is also formed by the reaction of a dithiolate with propargyl bromide in dimethylformamide, followed by acidification, when both nucleophilic substitution and addition of SH to the triple bond occur. The choice between the possible 4-methylene-1,3-dithiolan (XV) and 1,3-dithia-4-cyclohexene (XVI) structures was made on the basis of NMR measurements, which unambiguously show that the compound obtained was the dithiolan. XV contains the system CH(a)H(b)=C-CH₂(c) with $J_{ab} = 0-3.5$ cps and $J_{ac} = 0.5-2$ cps, whereas XVI contains the system CH(a)=CH(b)-CH₂(c), for which $J_{ab} = 6-14$ cps and $J_{bc} = 4-10$ cps.¹⁴ The experimental results (Table 6) are in accordance with the first possibility ($J_{ab} = J_{ac} = ca. 1.5$ cps).



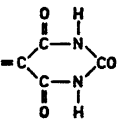
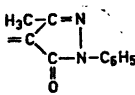
When, however, the reaction between propargyl bromide and the dithiolate was carried out in ethanolic solution, ring-closure occurred before the addition of acid and a different isomer was obtained. According to NMR measurements, this is the 4-methyl-1,3-dithiole (XVII). Its NMR spectrum (Table 6) is in accord with that reported for other compounds of this type, prepared from chloroacetone.⁹

The compounds of types VII, VIII, and XV should exist in *cis-trans*-isomeric forms, and the fact that the products, although giving correct analytical values, melt over a wide range indicates that they are mixtures of stereoisomers. It has, however, not been possible to isolate these in a pure state. By recrystallization of VIIIa from formic acid, a fraction with m.p. 147-153 (decomp.) and, on addition of hydrochloric acid to the mother liquor, another fraction with m.p. 126-128°C were obtained. In the NMR spectrum of the first fraction the signal from the SCH₂ group was found at 5.83 τ , whereas the other fraction showed two signals at 5.83 τ and 5.77 τ . This indicates that the high-melting form is one of the isomers while the

Table 7. Infrared bands (cm^{-1}) of derivatives of 1,1-dithiols (recorded from KBr discs on a Perkin-Elmer Model 337 grating spectrophotometer).

Compound				Correlation					
Type ^a	X	Y	R	$\text{C}\equiv\text{N}$	$\text{C}=\text{O}$	$\text{C}=\text{C} \begin{matrix} \diagup \text{S} \\ \diagdown \text{S} \end{matrix}$ or $\text{N}=\text{C} \begin{matrix} \diagup \text{S} \\ \diagdown \text{S} \end{matrix}$	$\text{S}-\text{C}(\text{alkyl})$		
I	CN	CN	Me	2215s 2190m		1445s	^b	880m	—
II	CN	CN		2220s 2210s		1495m 1475s	950m	856m	—
III	CN	CN		2220s 2210s		1470s 1450s	965m	860m	755w
IV			Me ^c	2185vs		1495vs	1020s 1040s	945s	—
V				2190s		1505s	1010m 985m	848m	
VI				2180s		1480s	1010m 995m	915w	—
VII	CN	CN		2220s		1465s	952m	885w	750m
IX	CN	CN		2226s	1726s	1476s	972m	840m	750m
XV	CN	CN		2230vs		1490vs	955s 895m	905s	740m
I	CN	CO_2Et	Me ^d	2217s	1700vs	1485s	1020m	910m	773m
II	CN	CO_2Et		2210s	1695vs	1485vs	1030s	940m 920s	768m 740m
III	CN	CO_2Et		2210m	1695s	1465s	1022s	905s	767m 731m
VIII	CN	CO_2Et		2200m	1730s 1695s	1503s	1025m	945m	767m 735w
IX	CN	CO_2Et		2215s	1720s 1685s	1470s	1025m		770m 730w
XIV	CN	CO_2Et		2205s	1675s	1470m	1032m	932m	758m 745m
XV	CN	CO_2Et		2220m	1700vs	1500vs	1025s	910m	770m 738m
XVII	CN	CO_2Et		2205s	1675s	1450s 1440s	1030s	940m	778w 760s
I	CO_2Me	CO_2Me	Me ^c		1730vs 1700vs	1525s	980m	950m	775w 748m
II	CO_2Me	CO_2Me			1700m 1670s	1485s	1010s	972m	780m 748w
III	CO_2Et	CO_2Et			1700s	1500s	1022s	930m 920m	783m 740w
IX	CO_2Me	CO_2Me			1720s 1680s	1486s	1005m	980m	792m 745m
I	H	CO_2Et	Me		1680s	1530s	1047m	920m	800m 735w
II	H	COPh			1620s	1480s	1045m 1025m	965w	765m
II	CO_2Et	COMe			1704vs 1630s	1406vs	1010m	915m	782m 750m
III	H	COPh			1620m	1502s	1040m 1022m	955w	777m
II	CN	Ph		2196s		1525s	—	925w	750m

Table 7. Continued.

III	CN	Ph	2190s	1510s	—	930m	770s 740m
II				1740s 1670m 1630s	1450vs	1055m	920m 792m 755w
II				1655s	1515vs	1000m	895s 762m
II	9-Fluorenylidene			1540s			

^a Roman numerals refer to the structural formulae.

^b Series of weak bands 900–985 cm^{-1} .

^c The benzyl derivatives show similar bands.

^d Compounds with R = CH_2Ph , $\text{CH}_2\text{CO}_2\text{H}$, or $\text{CH}_2\text{CO}_2\text{Me}$ show similar bands.

lower-melting is a mixture of both isomers. The infrared spectra showed small but reproducible differences.

Except for this partial separation it has not been possible to separate these compounds into isomers either by recrystallization or thin-layer chromatography. This seems to indicate that compounds of this type isomerize very easily to an equilibrium mixture. This premise is in accord with an NMR investigation¹¹ which shows that there is an unusually low barrier for rotation around the double bond in compounds of this type.

In their chemical reactions, these compounds (except for XV) show no double bond character. Ethyl 1,3-dithiolan-2-ylidenecyanoacetate (II; X = CN, Y = CO_2Et) could be recovered unchanged on attempts to add hydrogen (catalytically, with metal + acid or with $\text{SnCl}_2 + \text{HCl}$) and was unaffected by neutral KMnO_4 . Diethyl 1,3-dithiolan-2-ylidenemalonate formed an orange-red addition compound with bromine, but this gave off bromine again *in vacuo*. The substances are very resistant toward acid hydrolysis: 80% of dithiolanylidenebarbituric acid could be recovered after reflux with 6 N HCl for 6 h. On basic hydrolysis, the dithiolans form ethane-1,2-dithiol (nucleophilic replacement of the S–R groups).

INFRARED SPECTRA

A characteristic feature of the infrared spectra of all 1,1-ethylenedithiol derivatives and cyanoimidodithiocarbonates is a very intense band in the region 1300–1530 cm^{-1} (Table 7). In its unusual intensity and low frequency it differs very much from an ordinary C=C or C=N stretching vibration,

and it is perhaps most adequately described as the ν_1 vibration of a planar XYZ₂ structure, the C=CS₂ or N=CS₂ group (XVIII). This band is found at higher frequencies (1460–1530 cm⁻¹) in the spectra of compounds containing only ester groups and at lower frequencies (1430–1480 cm⁻¹) in the spectra of compounds containing groups (CN, NO₂, RCO) causing more extensive conjugation. In the ionic salts of the dithiols and their monoalkyl derivatives it is found at still lower frequencies (Table 8). When derivatives of the same

Table 8. Infrared bands (cm⁻¹) of metal dithiolates, assigned to the dithiolate structure (XVIII).

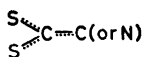
NC—N=C(SK) ₂	1320vs	1030s	970vs
(NC) ₂ C=C(SK) ₂ · H ₂ O ^a	1310vs	960vs	870s
(EtO ₂ C)(NC)C=C(SK) ₂ · H ₂ O ^b	1320vs	1020s	930vs
(EtO ₂ C) ₂ C=C=CS ₂ Zn	1450s	1030m	{ 920m 890m
(NC) ₂ C=C(SMe)(SNa) · H ₂ O	1340vs	1010s	865s
(EtO ₂ C)(NC)C=C(SMe)(SNa) ^c	1360vs	1030s	950s
	1340vs		

^a The sodium salt, (NC)₂C=C(SNa)₂ · 3H₂O shows an essentially identical spectrum.

^b The sodium, silver, and lead salts, and the salt (MeO₂C)(CN)C=C(SNa)₂ · 5H₂O show similar bands.

^c The *S*-ethyl, *S*-propyl, *S*-benzyl, *S*-methoxycarbonylmethyl, and *S*-ethoxycarbonylmethyl derivatives show similar bands. The band near 1360 cm⁻¹ is usually doubled.

dithiol are compared, the frequency of this band decreases in the series dialkyl derivative — monoalkyl derivative — heavy metal dithiolate — alkali metal dithiolate, *i.e.* with increasing electron-donating property of the sulfur group.



XVIII

The salt (KS)₂C=N—CN, which could be obtained anhydrous, shows a very simple infrared spectrum with three strong and sharp bands (1320vs, 1032s, 972vs) in addition to the intense C≡N stretching band (2150s). These three bands are assigned to the ν_1 , ν_4 , and ν_2 vibrations of the N=CS₂ structure. In the lower frequency range the infrared spectrum exhibits four weak bands (680, 595, 558, and 520 cm⁻¹), which might be due to the three remaining vibrations of the N=CS₂ structure (ν_6 , ν_3 , and ν_5) and the N—(CN) bending vibration. Although the spectra of the other metal dithiolates are more complicated, the three strong vibrations, ν_1 ($\sim\nu(\text{C}=\text{C})$ or $\nu(\text{C}=\text{N})$), ν_4 ($\sim\nu_{\text{as}}(\text{=CS}_2)$), and ν_2 ($\sim\nu_s(\text{=CS}_2)$), can easily be recognized (Table 8), and also the *S,S'*-dialkyl derivatives exhibit, in most cases, two rather conspicuous bands near 900–1000 cm⁻¹ in addition to the ν_1 band.

The assignment of the two bands in the 900–1050 cm⁻¹ region to C—S vibrations is corroborated by the fact that the infrared spectra of dialkyl

trithiocarbonates exhibit two strong bands in the same region. These bands are missing in the spectra of the corresponding triselenocarbonates, which instead have two bands in the 800–950 cm^{-1} region.¹⁵

Conjugation to the double bond of the dithiolate group causes a more pronounced lowering of the nitrile frequency (usually to 2180–2200 cm^{-1}) than ordinary $\alpha\beta$ -unsaturation. In the spectra of the salts containing two CN groups (*i.e.* $(\text{NC})_2\text{C}=\text{C}(\text{S}^-)_2$ and $(\text{NC})_2\text{C}=\text{C}(\text{SR})\text{S}^-$) the nitrile band is a doublet and there is an additional weak band at 2100 cm^{-1} . The *S,S'*-dialkyl derivatives with two CN groups usually also show a less pronounced doubling of the nitrile band. This splitting may of course be due to an unsymmetric field because the spectra were recorded from solid compounds or to a harmonic of the 1000 cm^{-1} band.

The C=O stretching band of the ester groups in these compounds is also lowered more than by usual $\alpha\beta$ -unsaturation; for most compounds it will be found near 1700 cm^{-1} , but in the spectra of the metal salts it may move down to 1620 cm^{-1} . The compounds containing an unconjugated ester group ($-\text{CH}_2\text{CO}_2\text{R}$) will, of course, show an additional C=O band at higher frequency (1740–1750 cm^{-1}).

A remarkable doubling of the C=O band is seen in the spectra of compounds containing two identical ester groups, for example $(\text{EtO}_2\text{C})_2\text{C}=\text{C}(\text{SMe})_2$. This may be due to steric hindrance which forces one of the ester groups out of the plane so that the two groups are no longer equivalent, but might also reflect a mechanical coupling. The lack of conjugation of the second ester group is also indicated by the fact that $\nu(\text{C}=\text{C})$ is almost the same for $(\text{EtO}_2\text{C})\text{HC}=\text{C}(\text{SMe})_2$ and $(\text{EtO}_2\text{C})_2\text{C}=\text{C}(\text{SMe})_2$.

The C=O stretching band of ketones is found in the normal place (1680–1700 cm^{-1}) for the dithiolanones (VIII) or dithianones (IX). For compounds which contain an acetyl or a benzoyl group directly attached to the central double bond, the C=O band is found at 1620–1630 cm^{-1} (but at 1700 cm^{-1} for the compound $(\text{NC})_2\text{C}=\text{C}(\text{SCOC}_6\text{H}_5)_2$).

The high- and low-melting forms of the dithiolanone (VIIIa) show practically identical infrared spectra, the main difference being that a medium-strong band at 1220 cm^{-1} is accompanied by a weak band at 1225 cm^{-1} only in the spectrum of the low-melting form.

1,3-Dithiolan-2-ylidenebarbituric acid and 1,3-dithian-2-ylidenebarbituric acid show three C=O bands (1740s, 1670m, 1630s), of which the band at highest frequency is assigned to the urea moiety of the barbituric acid (an "amide I band"). It is to be noted that there is no indication in the spectra of enolization of the barbituric acid derivatives.

The infrared spectra of the barbituric acid derivatives show very strong bands at 1450 cm^{-1} . *N*-Alkylation of the barbituric acid causes only small changes in the spectra.

4-(1',3'-Dithiolan-2'-ylidene)-3-methyl-1-phenyl-5-pyrazolone has a C=O band at 1655 cm^{-1} . The dithioic acid from which it was prepared shows no C=O band and accordingly is a real dithioic acid — not a dithiol — derived from the enol form of the pyrazolone (*i.e.* 5-hydroxy-3-methyl-1-phenyl-pyrazole-4-carbodithioic acid).

The compounds with an ordinary double bond (XV) show in addition to the "dithiolate band" a weak band in the usual place for a double bond ($1620-1630\text{ cm}^{-1}$). The C=C band of the dithiole ring is found at lower frequencies (XIV: 1535w , XVII: 1490m) and at the same time the "dithiolate band" is shifted to lower frequencies, indicating that the dithiolylium formula (XIV) contributes to the structure.

The influence of resonance structures of the type $>\text{C}=\overset{+}{\text{S}}-\text{R}$ would be expected to increase the R—S stretching frequency and the intensity of the band. While it is very difficult to make unambiguous assignments in the low frequency region, the fact that several of these compounds exhibit only very weak absorption between 500 and 700 cm^{-1} indicates that the R—S stretching band will be found above 700 cm^{-1} , *i.e.* at higher frequency than usual. Practically all the compounds investigated here (Table 7) show a medium to strong band near 770 cm^{-1} , often accompanied by a weaker band near 750 cm^{-1} . It is plausible that this band should be assigned to the S—C stretching of the S—R group. Because of the constancy of this band, there can normally only be slight coupling with other vibrations. In the spectra of some of the derivatives of cyanamide and malononitrile, however, there is only weak absorption below $800-900\text{ cm}^{-1}$ so that in these cases probably $\nu(\text{S}-\text{R})$ couples with vibrations of the dithiolate group.

Another consequence of the formal positive charge on S is that the deformation vibrations of a methyl group bonded to sulfur will give rise to a rather strong band near 1300 cm^{-1} — in addition to a band near 1400 cm^{-1} , found also in the spectra of other alkyl derivatives. However, for compounds containing ester groups the 1300 cm^{-1} band will be hidden by, or coupled with, the intense ester band appearing in the same region (all the esters show a very strong band in the $1250-1300\text{ cm}^{-1}$ region). While most of the compounds show the strong band in the $1000-1100\text{ cm}^{-1}$ region, the position of this band varies somewhat from methyl to ethyl esters, which indicates that this vibration of the dithiolate group couples with an ester vibration.

The amino- and hydroxythiophens (X and XI and their analogues) can easily be distinguished through their infrared spectra. The hydroxythiophens have a nitrile band at 2220 cm^{-1} and a hydroxyl band at 1152 cm^{-1} , whereas the aminothiophenes show absorptions due to a primary amino group (3510 , 3380 , and 1590 cm^{-1}).

EXPERIMENTAL

Preparation of alkali metal dithiolates

A number of these salts have been prepared by Söderbäck² whose directions were followed in most cases. We have prepared some of the salts several times and the limits of the yields are indicated in Table 1. Analyses have been satisfactory for C and N but the values for H have generally been too high, probably because the salts are very hygroscopic. In the following these salts have been called "dithiolate" with the number given in Table 1. Instead of the sodium salts it was found convenient, in most cases, to use the potassium salts which were prepared in dioxan or dioxan-ether solution and employed immediately after filtration without further purification. Some slightly soluble silver, lead, and zinc salts were prepared by precipitation.

Dithiolate 5. Pulverized potassium hydroxide (0.2 mol) was suspended in dioxan (100 ml) and a solution of ethyl cyanoacetate (0.1 mol) and carbon disulfide (0.1 mol) in dioxan (50 ml) was added with stirring and cooling to maintain a temperature of 15–20°C. After the addition, the suspension was stirred for another 20 min and diluted with 250 ml of ether. The yellow precipitate was filtered, washed with dioxan-ether (1:1) and dried *in vacuo* over NaOH and P₂O₅. Yield ~100%. For analysis the salt was dissolved in a little water and precipitated with 1-propanol. (Found: C 27.02; (H 3.04); N 5.14. Calc. for C₈H₈K₂NO₂S₂·H₂O: C 27.17; H 1.88; N 5.28). When excess potassium hydroxide was used, the yield diminished considerably.

The derivatives of diethyl malonate (dithiolate 2) and malononitrile (dithiolate 7) were prepared in essentially the same manner. The conditions of the preparation have been varied considerably without much change of the result, using dioxan or dioxan-ether as solvent, varying the temperature and reaction time, adding potassium hydroxide and carbon disulfide portionwise to a solution of the ester, *etc.*

The barbituric acid derivative (dithiolate 9) was prepared in the following manner: barbituric acid (9.6 g) was dissolved in a solution of 12 g of sodium hydroxide in 70 ml of water, 7.6 g of carbon disulfide was added and the mixture was kept in a closed bottle with magnetic stirring until the CS₂ layer had disappeared and a clear red solution had formed (*ca.* 1 day). The solution was poured into 200 ml of ethanol and the red oil that precipitated was separated and triturated with 100 ml of abs. ethanol at 0°C. This caused the oil to solidify. It was purified by dissolution in 70 ml of 5 N sodium hydroxide and addition of ethanol to the filtered solution. The resulting brick-coloured solid (21.90 g; 70%) was filtered, washed with ethanol and ether and dried over NaOH. According to analyses, it contained 8 molecules of water of crystallization.

Attempts were made to prepare sodium or potassium salts of monoesters by addition of one equivalent of alkyl halide (methyl iodide, propyl bromide, benzyl chloride) to the dithiolates, but the resulting compounds were difficult to purify and have only been obtained approximately pure. From dithiolate 5 and one equivalent of methyl iodide, a colourless, crystalline, hygroscopic compound was obtained which after recrystallization twice from water, twice from acetone-chloroform and twice from butanone-chloroform yielded analytical values corresponding approximately to the formula (C₂H₅O₂C)(CN)C=C(SCH₃)SNa·H₂O. (Found: C 34.61; H 4.82; S 26.00. Calc. for C₇H₁₀NNaO₅S₂: C 34.70; H 4.12; S 26.30). When hydrochloric acid was added to a solution of this salt in water, a yellowish precipitate was formed which after filtration, drying, and recrystallization from ether-pentane yielded analytical values corresponding to the methyl ester of the dithioic acid, (C₂H₅O₂C)(CN)CH—CSSCH₃. (Found: C 41.89; H 4.70; N 6.65. Calc. for C₇H₉NO₂S₂: C 41.37; H 4.47; N 6.89). M.p. 69–71°C (decomp.). This compound is very unstable. It rapidly became yellow and was transformed into an unidentified compound on attempted recrystallization from methanol.

Preparation of derivatives of ethylene-1,1-dithiols from isolated sodium or potassium dithiolates

Solutions of the alkali metal dithiolates react smoothly with reactive halogen compounds at room temperature. Several different solvents were tried (methanol, ethanol, ethanol-water, acetone, ethylene glycol, *etc.*) without much variation of the yields. However, if alcoholic solutions are used, care should be taken to use methanol with methyl esters and ethanol with ethyl esters, for otherwise transesterification may take place and the reaction product may be a mixture of a methyl and an ethyl ester (as was shown by isolation of both compounds by chromatography). Furthermore, aqueous solutions should not be used with esters because hydrolysis will diminish the yields.

The derivatives of 3-methyl-1-phenyl-5-pyrazolone were prepared from the free dithioic acid, to which two equivalents of sodium hydroxide were added.

The following examples illustrate the procedures used (for yields, melting points, and analyses, see Tables 2–5).

Ethyl [bis(methylthio)methylene]cyanoacetate (I; X = CN, Y = CO₂C₂H₅, R = CH₃). A solution of dithiolate 5 (2 mmol) and methyl iodide (4 mmol) in abs. ethanol (15 ml) was kept at 0°C for two days. The ethanol was removed by evaporation *in vacuo* and

water added to the residue. The insoluble solid was filtered and dried (yield 0.36 g, 83 %). On recrystallization from ether it yielded colourless crystals, m.p. 58.5–59°C. From ether-pentane and methanol it was obtained in a different crystal form with a lower melting point, apparently a polymorph.

The other *S*-methyl derivatives were prepared in a similar manner, but the derivative of diethyl malonate, which was liquid, was extracted with ether after addition of water. It was obtained as colourless crystals at low temperature (m.p. 12–15°C) and was also purified by distillation *in vacuo*.

[*Bis*(benzylthio)methylene]malononitrile (I; X = Y = CN, R = CH₂C₆H₅). A solution of dithiolate 6 (10 mmol) and benzyl chloride (20 mmol) in ethanol-water (2:1) was kept for 1 h at 50°C. On cooling, the dibenzyl derivative separated. The other benzyl derivatives were prepared in a similar manner, except that the reaction was performed at room temperature. With 4-nitrobenzyl chloride the best yield (86 %) was obtained when aqueous acetone (60 %) was used as solvent.

Ethyl [*bis*(carboxymethylthio)methylene]cyanoacetate (I; X = CN, Y = CO₂C₂H₅, R = CH₂CO₂H). An aqueous solution of dithiolate 4 (3.23 g; 10 mmol), bromoacetic acid (2.8 g; 20 mmol) and sodium hydrogen carbonate (1.7 g) was kept for 18 h at room temperature and then acidified with hydrochloric acid. The yellowish precipitate was filtered and recrystallized from water and methanol-water.

When only one equivalent of bromoacetic acid was used, the yellowish precipitate obtained by acidification of the solution was not a carboxylic acid (according to its infrared spectrum) and analyses after recrystallization corresponded to the 4-dithiolanone (*q.v.*). The same compound was formed when excess chloroacetic acid was used instead of bromoacetic acid because chloroacetic acid reacts more slowly with the dithiolate.

The other carboxymethyl derivatives (Table 2) were prepared in a similar manner. Their methyl esters were obtained from the sodium dithiolate and methyl chloroacetate in 60 % methanol.

Ethyl 1,3-dithiolan-2-ylidenecyanoacetate (II; X = CN, Y = CO₂C₂H₅). a) A solution of 1,2-dibromoethane (18.8 g) in ethanol (50 ml) was mixed with a solution of dithiolate 4 (32.3 g) in water (50 ml) and the solution was stirred for 15 min at room temperature and for 45 min at 45°C. Addition of water (50 ml) and cooling with ice afforded 21.2 g (98.5 %) of practically pure product (m.p. 105–106°C).

b) Dithiolate 5 (0.1 mol) was dissolved in 70 % ethanol (425 ml) and 1,2-dibromoethane (0.1 mol) was added. After 14 h the suspension was poured into 1.5 l of water and the precipitate filtered. Yield 18.6 g (88 %).

Diethyl 1,3-dithiolan-2-ylidenemalonate (II; X = Y = CO₂C₂H₅). 1,2-Dibromoethane (40 g) was added with stirring in the course of 30 min to a solution of dithiolate 2 (62.5 g) in 250 ml of abs. ethanol (room temperature). After 1 ¼ h the ethanol was removed *in vacuo* and the residue was dissolved in water and extracted with ether. The ether solution was dried with magnesium sulfate and the ether removed by evaporation *in vacuo*. The residue was an orange-coloured oil which crystallized on standing. The yellow crystals were washed with ether-petroleum ether (1:1) and recrystallized from methanol and from ether. Yield 29.1 g of crude product and 25.0 g (48 % relative to the salt, 42 % relative to diethyl malonate) of the pure dithiolan, m.p. 59–60°C.

Diethyl 1,3-dithian-2-ylidenemalonate (III; X = Y = CO₂C₂H₅) was prepared in a similar manner, but the reaction was slower. The solution was left for 24 h and 1 g of potassium iodide was added to accelerate the reaction.

1,3-Dithiolan-2-ylidenecyanamide (V). A solution of dithiolate 8 (4 mmol) and 1,2-dibromoethane (4 mmol) in ethylene glycol (2 ml) was shaken for 5 h. The resulting milky suspension was diluted with 8 ml of water and heated to boiling. On cooling, a crystalline precipitate separated. Yield 0.25 g (43 %) of crude product which after recrystallization three times from methylene chloride-petroleum ether had m.p. 79–79.5°C.

3-Methyl-1-phenyl-4-(1',3'-dithiolan-2'-ylidene)-5-pyrazolone. 5-Hydroxy-3-methyl-1-phenyl-pyrazole-4-carbodithioic acid (1 mmol), 1,2-dibromoethane (1 mmol) and sodium hydroxide (2 mmol) were dissolved in 50 % aqueous acetone. On standing of the solution at room temperature for 2 h, a yellow crystalline precipitate separated. It was filtered, dried and recrystallized twice from methanol.

5-(1',3'-Dithiolan-2'-ylidene)barbituric acid. a) To a solution of 6.7 g of dithiolate 9 in 40 ml of water and 2 ml of 1 N hydrochloric acid was added a solution of 3.8 g of 1,2-dibromoethane in 50 ml of ethanol. After 17 h the yellowish precipitate which had

separated was filtered and washed with water, ethanol and ether. Recrystallization from dimethylformamide afforded 2.5 g of a colourless substance.

b) Urea (70 mmol) and diethyl 1,3-dithiolan-2-ylidenemalonate (50 mmol) were added to a hot solution of potassium 2-propanolate (20 mmol) in 2-propanol (100 ml). The mixture was refluxed for 1 h, cooled and acidified with 4 N hydrochloric acid. The solid was filtered off and washed with ethanol and ether. Yield 11.2 g (99 %). Its infrared spectrum was identical with that of the product prepared according to a).

5-(1',3'-Dithiolan-2'-yliden)-1-ethylbarbituric acid. Methyl-1,3-dithiolan-2-ylidene-malonate (10 mmol) and *N*-ethylurea (10 mmol) were added to a solution of sodium methanolate (10 mmol) in dry methanol (10 ml). The mixture was refluxed for 3 h and the solvent evaporated *in vacuo*. Addition of water and dilute sulfuric acid to the residue yielded 2.2 g (85 %) of crude product. Recrystallization from methanol gave the pure product, m.p. 304–306°C (decomp.). (Found: C 42.00; H 4.08; N 10.71. Calc. for $C_9H_{10}N_2O_5S_2$: C 41.84; H 3.90; N 10.85).

4-Methylene-1,3-dithiolan-2-ylidenemalononitrile (XV; X = Y = CN). Propargyl bromide (10 mmol) was added to a solution of dithiolate 6 (10 mmol) in dimethylformamide (50 ml). The reaction mixture was stirred for 5 min at room temperature, diluted with water (60 ml) and acidified with hydrochloric acid (20 mmol). After 1 day a crystalline light yellow precipitate was filtered and dried. Yield 1.1 g (61 %). Recrystallization from toluene-heptane (1:3) and from methanol-water gave a light-yellow product, m.p. 125–126°C.

Ethyl 4-methylene-1,3-dithiolan-2-ylidenecyanoacetate was prepared in the same manner from dithiolate 4.

Ethyl 4-methyl-1,3-dithiol-2-ylidenecyanoacetate (XVII; X = CN, Y = $CO_2C_2H_5$). Propargyl bromide (10 mmol) was added to a solution of dithiolate 4 (10 mmol) in ethanol (40 ml). The reaction mixture was stirred at room temperature for 1 h, diluted with water (60 ml) and acidified with hydrochloric acid. The precipitated material was filtered and dried. Yield 1.35 g (60 %). The crude product was recrystallized from heptane and methanol-water. M.p. 124–127°C. (Found: C 47.30; H 3.85; N 6.08. Calc. for $C_9H_9NO_2S_2$: C 47.58; H 3.97; N 6.17).

Ethyl 4-hydroxy-1,3-dithiolan-2-ylidenecyanoacetate (VII; X = CN, Y = $CO_2C_2H_5$). Chloroacetaldehyde (10 mmol) was added to a solution of dithiolate 4 (10 mmol) and potassium dihydrogen phosphate (10 mmol) in water (50 ml). A nearly colourless precipitate separated immediately and was collected after cooling of the reaction mixture. Yield 2.3 g (100 %) of product, which after recrystallization from toluene-heptane (1:1) had m.p. 109–117°C. Further recrystallization may or may not give a product with a sharper melting point, probably because the material is a mixture of easily interconvertible *cis-trans* isomers.

Ethyl 1,3-dithiol-2-ylidenecyanoacetate (XIV). The foregoing compound (520 mg) was dissolved in conc. sulfuric acid (10 ml). The solution was poured into ice-water and the precipitate was collected and dried. Yield of crude product 480 mg. Preparative layer chromatography on silica gel afforded 315 mg (66 %) of a light-yellow solid, m.p. 175–177°C. (Found: C 45.30; H 3.22; N 6.36; S 30.23. Calc. for $C_8H_7NO_2S_2$: C 45.07; H 3.29; N 6.57; S 30.05).

4-Hydroxy-1,3-dithiolan-2-ylidenemalononitrile (VII; X = Y = CN). Chloroacetaldehyde (10 mmol) was added to a solution of dithiolate 6 (10 mmol) in water (100 ml) and the reaction mixture was left for 1 h at room temperature. Hydrochloric acid (10 mmol) was added and the mixture again left for 1 h. A light brown precipitate was obtained (1.02 g; 55 %), which after recrystallization from toluene and methanol-water (+ active carbon) afforded a colourless product, m.p. 168–175°C (decomp.).

Ethyl 4-oxo-1,3-dithiolan-2-ylidenecyanoacetate (VIII; X = CN, Y = $CO_2C_2H_5$). a) A solution of bromoacetic acid (50 mmol) and sodium hydrogen carbonate (50 mmol) in water (50 ml) was mixed with a solution of dithiolate 4 (50 mmol) in water (150 ml). After 2 h hydrochloric acid (0.1 mol) was added and the mixture was left in a refrigerator for 1 day. A nearly colourless precipitate was separated and dried. Yield 10.2 g (89 %).

b) Dithiolate 4 (50 mmol) was dissolved in methanol (100 ml) and ethyl bromoacetate (50 mmol) was added. The mixture was stirred for 15 min at room temperature, diluted with water and acidified with conc. hydrochloric acid. After 16 h at 0°C a nearly colourless crystalline precipitate had separated. Yield 10.8 g (94 %).

Recrystallization of the crude products thus obtained from nonpolar solvents (methylene chloride, toluene, heptane) afforded a substance which gave analytical values corresponding to the expected formula but melted over a wide range (130–150°C). Recrystallization from water or methanol separated the crude products into fractions with m.p. 147–154 and 125–130°C, though with simultaneous formation of a substantial amount of a red-brown tar. This could be circumvented by recrystallizing from formic acid, from which a higher-melting fraction separated on cooling and a lower-melting fraction after dilution with hydrochloric acid. Thin-layer chromatography on silica gel only afforded well-defined spots when a few percent of formic or acetic acid was added to the solvent. By developing six times with pentane-methylene chloride (2:1, with 2 % of formic acid) only one spot with identical R_F values was formed from each of the two fractions.

Dimethyl 3-amino-5-(methylthio)thiophene-2,4-dicarboxylate (X) and methyl 4-cyano-3-hydroxy-5-(methylthio)thiophene-2-carboxylate (XI). a) A mixture of dithiolate 4 (50 mmol) dissolved in dimethylformamide (100 ml) and methyl chloroacetate (50 mmol) was stirred for 15 min at room temperature and then methyl iodide (50 mmol) was added. After 1 h at room temperature the mixture was diluted with water and extracted with ether. The dried ether layer left on evaporation 10.8 g of a light yellow oil; 2.75 g of this product was dissolved in methanol (20 ml) and sodium methanolate (10 mmol) was added. The mixture was left for 2 h at 30°C, poured into water, acidified with hydrochloric acid, and extracted with chloroform. The aqueous layer was made alkaline and again extracted with chloroform. The combined chloroform extracts were extracted with dilute potassium hydroxide.

The chloroform layer left on evaporation a residue which on recrystallization from heptane yielded colourless crystals of the aminothiophen (X). Yield 27 %. M.p. 136–138°C. (Found: C 41.48; H 4.24; N 5.34. Calc. for $C_9H_{11}NO_4S_2$: C 41.38; H 4.21; N 5.36).

The hydroxythiophen (XI) was isolated by acidifying the aqueous layer and extracting with chloroform. It formed colourless crystals from toluene (yield 30 %), m.p. 164–166°C. (Found: C 41.98; H 3.14; N 6.02. Calc. for $C_9H_9NO_3S_2$: C 41.92; H 3.06; N 6.11).

b) Ethyl 4-oxo-1,3-dithiolan-2-ylidenecyanoacetate (5 mmol) and methyl iodide (5 mmol) were dissolved in methanol (80 ml) and the solution was stirred for 2 days with calcium carbonate (0.25 g). The solvent was evaporated and the residue dissolved in chloroform, which was washed with water, dried and evaporated. The residue was dissolved in methanol (80 ml) and sodium methanolate (5.5 mmol) was added. The mixture was stirred for 3 h and the products were separated as above. Yield 14 % of X and 31 % of XI.

The simultaneous formation of an aminothiophen and a hydroxythiophen was also demonstrated by treatment of $(EtO_2C)(CN)C=C(SCH_2CO_2Me)_2$ with sodium methanolate and separation of the reaction products as above. Amino compound: m.p. 123–124°C (heptane). (Found: C 43.21; H 4.05; N 4.29. Calc. for $C_{12}H_{15}NO_4S_2$: C 43.24; H 4.50; N 4.20). The hydroxy compound, isolated by acidification of the alkaline extract, proved to be a carboxylic acid, hydrolysis of the $-SCH_2CO_2CH_3$ group having taken place. (Found: C 40.12; H 2.50; N 4.97. Calc. for $C_9H_7NO_5S_2$: C 39.56; H 2.58; N 5.15). M.p. 169–171°C (toluene).

5-Oxo-1,3-dithian-2-ylidenemalononitrile (IX; X = Y = CN). 1,3-Dichloroacetone (10 mmol) dissolved in acetone (5 ml) was added to a solution of dithiolate 4 (10 mmol) in ice-cold water (50 ml), the mixture was left for 36 h at 0°C, and the colourless precipitate was isolated. Yield 1.59 g (81 %). M.p. 150–151°C after recrystallization from toluene and heptane.

[Bis(benzoylthio)methylene]malononitrile. 1.2 g (5 mmol) of dithiolate 6 was suspended in 25 ml of ether and 1.4 g (10 mmol) of benzoyl chloride and 25 ml of dioxan were added to the stirred solution. The stirring was continued for 16 h, after which the solution was filtered from sodium chloride and concentrated *in vacuo* to 1/3 of its original volume. On cooling, an orange-yellow crystalline compound separated. On recrystallization three times from ether, 0.18 g (10 %) of a colourless substance was obtained. M.p. 122–126°C (decomp.). (Found: C 61.60; H 3.11. Calc. for $C_{18}H_{10}N_2O_2S_2$: C 61.70; H 3.11).

Attempts to prepare a corresponding dibenzoyl derivative from dithiolate 4 resulted in the formation of 2,4-bis[cyano(ethoxycarbonyl)methylene]-1,3-dithiethan (*cf.* Gompfer and Töpfl³). The compound was precipitated from the dioxan solution by addition of pentane and recrystallized from ether-acetone. Yield 8 % of colourless crystals with

m.p. 164–169°C (decomp.). (Found: C 46.65; H 3.19; N 8.68; S 20.50. Calc. for $C_{12}H_{10}N_2O_4S_2$: C 46.43; H 3.25; N 9.03; S 20.66).

2-(*p*-Bromophenacylthio)-5-*p*-bromobenzoylthiazole-4-amine (XIII). *p*-Bromophenacyl bromide (1.1 g; 4 mmol) was added to a solution of dithiolate 8 (0.39 g; 2 mmol) in methanol (30 ml). An exothermic reaction took place while a colourless solid precipitated. Yield after recrystallization from ethyl acetate 0.44 g (43 %). M.p. 203–204°C. The infrared spectrum of this substance showed no nitrile band but NH_2 bands, indicating that ring-closure to a thiazole had taken place. (Found: C 42.02; H 2.25; N 5.31. Calc. for $C_{18}H_{12}Br_2N_2O_2S_2$: C 42.20; H 2.36; N 5.47).

In a similar manner *p*-bromophenacyl bromide and dithiolate 6 yielded a substance which must be formulated as 2-*p*-bromobenzoyl-4-cyano-5-(*p*-bromophenacylthio)thiophen-3-amine (XII) since its infrared spectrum exhibits NH_2 bands (it also shows a nitrile band, so ring-closure has only taken place with one of the *p*-bromophenacyl groups). From 2 mmol of *p*-bromophenacyl bromide, 0.39 g (75 %) of crude product was obtained. After recrystallization three times from ethyl acetate, its m.p. was 201–202°C. (Found: C 44.90; H 2.26. Calc. for $C_{20}H_{12}Br_2N_2O_2S_2$: C 44.79; H 2.26).

Preparation of derivatives of ethylene-1,1-dithiols directly from reactive methylene compounds (without isolation of dithiolates)

With the more pronouncedly acidic methylene compounds (ethyl cyanoacetate, malononitrile), the choice of solvent and base is not very critical; excellent yields have, *e.g.*, been obtained with ethanol as the solvent (see the following example). With the less acidic substances (acetophenone, benzyl cyanide, *etc.*), yields have been low (10–30 %) in alcoholic solutions and much better yields have been obtained with dimethylformamide as solvent. The use of sodium 2-methyl-2-butanolate as the base has often proved advantageous in these cases. A great number of other bases have been investigated – sodium hydride, lithium hydride, phenyllithium, benzylsodium, lithium diethylamide – and use of the lithium or magnesium salts of the methylene compounds (prepared by reaction with the metals) was also tried but led to either negative results or much diminished yields. With sodium hydride in dimethylformamide methyl dimethyldithiocarbamate has repeatedly been obtained as the main product.

The following examples illustrate the preferred conditions of preparation. Sodium methanolate was prepared by evaporation of a methanolic solution *in vacuo* at 40°C. If the temperature was raised to 100°C, the product was no longer soluble in dimethylformamide. Sodium 2-methyl-2-butanolate was added in benzene solution.

Ethyl 1,3-dithiolan-2-ylidenecyanoacetate (II; X = CN, Y = $CO_2C_2H_5$) was prepared from ethyl cyanoacetate (8.5 g; 75 mmol), carbon disulfide (4.5 ml) and 2.5 M ethanolic sodium ethanolate (60 ml) in abs. ethanol (60 ml). Half of the carbon disulfide and half of the sodium ethanolate were added at once and the remaining portions were added synchronously with stirring and cooling in ice. 1,2-Dibromoethane (14.5 g) was added slowly, keeping the temperature at 20–30°C. The stirring was continued for 20 h and the solution poured into 1.5 l of water. The colourless crystalline precipitate was filtered, washed with water and dried. Yield 97 % of crude product, m.p. 102–107°C (106–107°C after recrystallization from methanol).

Dimethyl 1,3-dithiolan-2-ylidenemalonate (II; X = Y = CO_2CH_3). Sodium methanolate, obtained by evaporation of 10 ml of a 2.75 M solution *in vacuo*, was dissolved in 25 ml of dimethylformamide and dimethyl malonate (27.5 mmol) and carbon disulfide (13.75 mmol) were added. After 5 min, a red solution had formed and 1,2-dibromoethane (13.75 mmol) was added. The solution was heated to boiling, and water was added until recrystallization began. On cooling, a yellowish precipitate separated. Yield 2.7 g (84 %). Recrystallization from ether afforded 1.9 g of colourless crystals.

Diethyl 1,3-dithian-2-ylidenemalonate (III; X = Y = $CO_2C_2H_5$) was obtained in a similar manner from diethyl malonate, potassium hydroxide, carbon disulfide and 1,3-dibromopropane in dimethylformamide.

2-(*Fluoren-9-ylidene*)-1,3-dithiolan. To a solution of fluorene (100 mmol) in dimethylformamide (70 ml) were added successively 100, 50, and 50 mmoles of sodium 2-methyl-2-

butanolate in benzene together with 50, 25, and 25 mmoles of carbon disulfide, keeping the temperature below 15°C. Addition of 1,2-dibromoethane (100 mmol) to the resulting solution gave rise to an exothermic reaction. The solution was left for 12 h and diluted with 500 ml of water. The reaction product was extracted with ether and the ether solution dried with magnesium sulfate. After removal of the ether by evaporation, addition of petroleum ether and cooling a yellow crystalline substance was obtained. Yield 20.9 g (78 %).

In a similar manner *ethyl 1,3-dithiolan-2-ylideneacetoacetate* was prepared from ethyl acetoacetate (yield 69 %). It has also been prepared with sodium methanolate as the base (yield 73 %), but in another experiment with this base the main product was ethyl β,β -di(methylthio)acrylate, $(\text{CH}_3\text{S})_2\text{C}=\text{CH}-\text{CO}_2\text{C}_2\text{H}_5$, m.p. 55.5°C after recrystallization from ether. This compound has also been obtained as a by-product in a similar reaction by Laakso.¹

Most of the other dithiolans and dithians (Tables 3 and 4) were prepared by the same procedure. However, on various occasions sodium or potassium hydroxides have been used instead of sodium 2-methyl-2-butanolate without diminution of the yield when the reaction was performed in dimethylformamide.

Acknowledgement. We wish to thank Dr. Martin Ettliger for some very valuable discussions.

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Received November 6, 1967.