THE PREPARATION OF SUBSTITUTED THIONOCARBAMATES[1]

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ABSTRACT

The preparations and properties of a number of substituted thionocarbamates are described.

The thionocarbamate derivatives in Tables I–IV were prepared by one of the following three methods:

$$\mathrm{ROH + CSCl_2 \xrightarrow{-HCl} ROC(S)Cl + R'NH_2 \xrightarrow{-HCl} R'NHC(S)OR,} \qquad [1]$$

$$\mathrm{ROH + R'NCS \xrightarrow{(C_2H_5)_3N} R'NHC(S)OR,} \qquad [2]$$

$$\mathrm{ROH + R'NCS \xrightarrow{NaH} R'NHC(S)OR.} \qquad [3]$$

Route 1 was used to prepare both the aryl arylthionocarbamates and the aryl aralkylthionocarbamates. Procedure 2 gave good results with aralkyl isothiocyanates but triethylamine did not catalyze the addition of aryl isothiocyanates to phenols under the conditions employed in this study. All of the benzyl N-substituted thionocarbamates were prepared by procedure 3.

Harris and Fischback (1) reported the preparation of thionocarbamates by the reaction of amines with methyl xanthates. An attempt to prepare phenyl 3,4-dichlorobenzylthionocarbamate from S-methyl phenylxanthate by this procedure gave methyl 3,4-dichlorobenzyldithiocarbamate. Thus the phenoxy group was replaced more readily by 3,4-dichlorobenzylamine than the methylmercapto group. However, if 3,4-dichlorobenzylamine is added to S-methyl ethylxanthate the methylmercapto group is replaced and ethyl 3,4-dichlorobenzylthionocarbamate is formed. These reactions are represented by equations 4 and 5.

[4]

$$\mathrm{RNH_2 + C_2H_5OC(S)SCH_3 \longrightarrow RNHC(S)OC_2H_5 + CH_3SH} \qquad [5]$$

$$\mathrm{R = 3,4\text{-}Cl_2C_6H_3CH_2—}$$

The thiolcarbamates in Table V were prepared by treating the corresponding phenyl chlorothiolformates with the appropriate amines. The phenyl chlorothiolformates were obtained by treating the lead salts of the thiophenols with phosgene by the method of Rivier (2).

An attempt to prepare phenyl 3,4-dichlorobenzylthionocarbamate by heating a methanolic solution of methyl 3,4-dichlorobenzyldithiocarbamate in the presence of Amberlite IRA-400 resin saturated with phenol gave methyl 3,4-dichlorobenzylthionocarbamate in 48% yield.

The aryl chlorothionoformates, which were isolated during these studies, are described in Table VI.

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EXPERIMENTAL[2]

Di-3,4-dichlorobenzylamine

A mixture of 3,4-dichlorobenzyl chloride (9.75 g, 0.05 mole) and 3,4-dichlorobenzylamine (35.2 g, 0.20 mole) was heated on the steam bath for 2 hours. Ether (200 ml) and 10% sodium hydroxide solution (50 ml) were added, and the ether layer was washed with water and dried over anhydrous sodium sulphate. Fractionation of the ether extract yielded 15 g (85.2%) of unchanged 3,4-dichlorobenzylamine (b.p. 93–100°/1 mm) and di-3,4-dichlorobenzylamine (b.p. 175–180°/1 mm, n_D^{25} 1.60665, D_4^{27} 1.3690), yield 10 g (59.7%). Anal. Calc. for $C_{14}H_{11}Cl_4N$: C, 50.20; H, 3.31; Cl, 42.34; N, 4.18. Found: C, 50.68; H, 3.44; Cl, 42.00; N, 4.13.

A solution of the amine (0.61 g, 0.0018 mole) in absolute ethanol (30 ml) was acidified with hydrogen chloride. Di-3,4-dichlorobenzylamine hydrochloride (m.p. 228–229°) was recovered by filtration, yield 0.21 g (33%). Anal. Calc. for $C_{14}H_{12}Cl_5N$: C, 45.26; H, 3.26; Cl, 47.72; N, 3.77. Found: C, 45.17; H, 3.09; Cl, 47.80; N, 3.98. N-4-Chlorobenzylaniline (3) (b.p. 155°/0.5 mm) and di-4-chlorobenzylamine (m.p. 30–32°) were prepared in the same way in 62.8% and 60% yield respectively. A melting point of 31° has been reported (4) for di-4-chlorobenzylamine.

2-(3,4-Dichlorophenyl)-acetonitrile

A solution of 3,4-dichlorobenzyl chloride (48.87 g, 0.25 mole) in ethanol (50 ml) was added during 30 minutes to a stirred solution of potassium cyanide (19.50 g, 0.30 mole) in water (15 ml) at 60°. The mixture was refluxed for 4 hours, and then cooled and filtered. The filtrate was concentrated *in vacuo* and the residue was extracted with ether (100 ml). The ether solution was dried and evaporated, and the residue was distilled to give the product (b.p. 106–108°/0.1 mm; m.p. 35.5–38.5°), yield 37.6 g (81%). Recrystallization from ether – petroleum ether raised the melting point to 39.5–40.5°. Anal. Calc. for $C_8H_5Cl_2N$: C, 51.65; H, 2.71; Cl, 38.12; N, 7.53. Found: C, 51.81; H, 2.92; Cl, 38.14; N, 7.56.

2-(3,4-Dichlorophenyl)-ethylamine

Aluminum chloride (6.66 g, 0.05 mole) in ether (150 ml) was added to a suspension of lithium aluminum hydride (1.99 g, 0.05 mole) in ether (100 ml) maintained in a nitrogen atmosphere. A solution of 2-(3,4-dichlorophenyl)-acetonitrile (9.3 g, 0.05 mole) in ether (200 ml) was added dropwise to the stirred mixture, and the stirring was continued for 30 minutes. Water was added cautiously to destroy the excess lithium aluminum hydride and after further addition of water (total 140 ml) and 6 *N* sulphuric acid (140 ml), the aqueous layer was separated and washed with ether (100 ml). The aqueous layer was basified with 40% sodium hydroxide solution at 0°, and the free base was extracted with ether (3×150 ml). Fractionation of the dried ether extract yielded the product (b.p. 100–102°/0.12 mm), yield 6.75 g (71%). Anal. Calc. for $C_8H_9Cl_2N$: C, 50.56; H, 4.78; Cl, 37.32; N, 7.37. Found: C, 50.25; H, 4.92; Cl, 37.16; N, 7.22.

The amine in aqueous ethanol was converted into its picrate (m.p. 199–200°, decomp.) in the usual manner, yield 67.5%. Anal. Calc. for $C_{14}H_{12}Cl_2N_4O_7$: C, 40.12; H, 2.89; Cl, 16.92; N, 13.37. Found: C, 40.15; H, 3.14; Cl, 17.06; N, 13.50.

3-(3,4-Dichlorophenyl)-propionic Acid

3,4-Dichlorobenzaldehyde was converted to 3,4-dichlorocinnamic acid (m.p. 214–217° C) in 69.2% yield by the method of Walling and Wolfstirn (5).

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[2] *All melting points are uncorrected. Microanalyses were performed by Micro-Tech Laboratories, Skokie, Illinois.*

3,4-Dichlorocinnamic acid (58.5 g, 0.27 mole) in glacial acetic acid (1500 ml) was hydrogenated at atmospheric pressure in the presence of 5% palladium on charcoal (5.8 g). The absorption of hydrogen ceased after 10.5 hours (6 liters). The solution was filtered and evaporated, and the residue was crystallized from water to give the product (m.p. 90–93°), yield 53.0 g (90%). Recrystallization from ethanol raised the melting point to 96–97°. Anal. Calc. for $C_9H_8Cl_2O_2$: C, 49.34; H, 3.68; Cl, 32.37. Found: C, 49.07; H, 3.68; Cl, 32.41.

3-(3,4-Dichlorophenyl)-propionamide

A solution of 3-(3,4-dichlorophenyl)-propionic acid (53.0 g, 0.24 mole) and thionyl chloride (119 g, 1.0 mole) in benzene (100 ml) was allowed to stand overnight, and was then evaporated to dryness. The oily residue was added in portions to 28% aqueous ammonia (270 ml) with stirring at 20–25° and the mixture was stirred for 4 hours. The product (m.p. 76–80°) was recovered by filtration, yield 45.5 g (86.3%). Recrystallization from benzene – petroleum ether raised the melting point to 80–81°. Anal. Calc. for $C_9H_9Cl_2NO$: C, 49.56; H, 4.16; Cl, 32.51; N, 6.42. Found: C, 49.78; H, 4.22; Cl, 32.67; N, 6.42.

3-(3,4-Dichlorophenyl)-propionitrile

A solution of the amide (37.9 g, 0.174 mole) and thionyl chloride (119 g, 1.0 mole) in benzene (200 ml) was refluxed for 5 hours, and the solution was then evaporated. Distillation of the residue yielded crude 3-(3,4-dichlorophenyl)-propionitrile (b.p. 140–158°/1 mm), yield 30.8 g (88%). Redistillation gave the pure product (b.p. 121°/0.4 mm, n_D^{25} 1.55403; d_{20} 1.2742). Anal. Calc. for $C_9H_7Cl_2N$: C, 54.02; H, 3.53; Cl, 35.44; N, 7.01. Found: C, 54.24; H, 3.66; Cl, 35.38; N, 7.03.

3-(3,4-Dichlorophenyl)-propylamine

3-(3,4-Dichlorophenyl)-propionitrile (18.0 g, 0.09 mole) was reduced by lithium aluminum hydride – aluminum chloride in ether exactly as described above for 2-(3,4-dichlorophenyl)-acetonitrile. The product (b.p. 120–125°/1 mm) was obtained in 17.3 g (95%) yield. A redistilled sample (b.p. 104°/0.4 mm, n_D^{27} 1.55487, d_{20} 1.2082) was submitted for analysis. Anal. Calc. for $C_9H_{11}Cl_2N$: C, 52.96; H, 5.43; Cl, 34.75; N, 6.87. Found: C, 53.08; H, 5.45; Cl, 34.73; N, 7.09.

The picrate of the amine, which was prepared in quantitative yield from water, melted at 150–151° after recrystallization from hot water. Anal. Calc. for $C_{15}H_{14}Cl_2N_2O_7$: C, 41.59; H, 3.26; Cl, 16.37; N, 12.93. Found: C, 41.69; H, 3.21; Cl, 16.53; N, 12.84.

Preparation of 4-n-Alkylphenols

A series of 4-*n*-alkylphenols, three of which are new, was prepared by the general method of Sandulesco and Girard (6).

4-n-Hexylphenol

4-*n*-Hexylphenol (b.p. 135–136°/0.4 mm) was prepared in 72.6% yield from *p*-caproylphenol. The reported (6) boiling point at 10 mm is 146–147°.

4-n-Decylphenol

Decanoyl chloride (69 g, 0.35 mole) was heated with phenol (32.9 g, 0.35 mole) at 120° for 1 hour. The crude phenyl decanoate was added during a 30-minute period to a suspension of anhydrous aluminum chloride (56 g, 0.42 mole) in carbon disulphide (100 ml). The reaction was exothermic and the solvent began to reflux during the addition. Refluxing was continued for 2 hours. The solution was then evaporated to dryness, and the residue was heated at 150° for 2 hours. Hydrochloric acid (200 ml of 18% HCl) was added cautiously and the mixture was diluted with water (150 ml). The oily product was extracted with chloroform (200 ml) and the chloroform solution was dried and evaporated. Fractionation of the residue yielded 2-decanoylphenol (b.p. 130–133°/0.25 mm), yield 42.8 g (49.4%), and 4-decanoylphenol (b.p. 194–195°/0.4 mm), yield 15 g (17.3%). The *p*-isomer (m.p. 59–60°) crystallized in the receiver. Anal. Calc. for $C_{16}H_{24}O_2$: C, 77.38; H, 9.74. Found: C, 77.26; H, 9.79.

4-Decanoylphenol (10 g, 0.04 mole) in ethanol (50 ml) was added to a vigorously stirred suspension of amalgamated zinc (70 g) in 18% hydrochloric acid (140 ml) and the reaction mixture was refluxed for 2 hours. The mixture was extracted with toluene (100 ml) and the toluene solution was dried and evaporated. Fractionation of the residue gave 7.8 g (83%) of 4-*n*-decylphenol (b.p. 146–148°/0.75 mm). The product crystallized (m.p. 54–56°) on standing. Anal. Calc. for $C_{16}H_{26}O$: C, 82.00; H, 11.19. Found: C, 81.83; H, 11.01.

4-n-Dodecylphenol

Phenol was heated with dodecanoyl chloride under similar conditions to form phenyl dodecanoate, which was rearranged to yield 51% of 2-dodecanoylphenol (b.p. 140–165°/0.75 mm), and 29.5% of 4-dodecanoylphenol (b.p. 198°/0.25 mm). Reduction of 4-dodecanoylphenol with amalgamated zinc and hydrochloric acid gave 4-*n*-dodecylphenol (b.p. 154°/3 mm, m.p. 65–67°), yield 81%. Anal. Calc. for $C_{18}H_{30}O$: C, 82.38; H, 11.53. Found: C, 82.48; H, 11.58.

4-n-Octadecylphenol

A mixture of stearic acid (113 g, 0.4 mole) and thionyl chloride (143 g, 1.2 mole) was refluxed for 1 hour. The mixture was distilled to give octadecanoyl chloride (b.p. 159–162°/0.1 mm), yield 87.9 g (72.5%). The acid chloride was converted to phenyl *n*-octadecanoate, which was rearranged to 31.6% of 2-*n*-octadecanoylphenol (b.p. 164–182°/0.15 mm) and 28% of 4-*n*-octadecanoylphenol (b.p. 209–212°/0.15 mm). Reduction of the para-isomer gave 4-*n*-octadecylphenol (b.p. 182–187°/0.15 mm, m.p. 65–67°) in 83% yield. Anal. Calc. for $C_{24}H_{42}O$: C, 83.18; H, 12.22. Found: C, 83.10; H, 12.00.

Aryl Thionocarbamates

Method A: 4-n-Propylphenyl 3,4-Dichlorophenylthionocarbamate

4-*n*-Propylphenol (20.43 g, 0.15 mole) in 3% sodium hydroxide solution (200 ml) was added to a stirred solution of thiophosgene (17.25 g, 0.15 mole) in chloroform (200 ml) at 0–10° during a period of 30 minutes. The stirring was continued for 30 minutes and the chloroform layer was separated, dried, and evaporated. Distillation of the residue gave 4-*n*-propylphenyl chlorothionoformate (b.p. 101–102°/0.8 mm), yield 24 g (74.7%).

3,4-Dichloroaniline (16.2 g, 0.1 mole) in chloroform (150 ml) was added to a stirred solution of 4-*n*-propylphenyl chlorothionoformate (10.73 g, 0.05 mole) in chloroform (200 ml) at 25° during a period of 30 minutes. The stirring was continued for 1 hour, and the precipitated 3,4-dichloroaniline hydrochloride (9.6 g, 97%) was removed by filtration. The filtrate was concentrated to a volume of 200 ml and petroleum ether (300 ml) was added to give the product (m.p. 150–151°), yield 12.6 g (74%). Recrystallization from the same solvents did not raise the melting point. When the phenol was insoluble in dilute sodium hydroxide, the dried sodium phenoxide was reacted with thiophosgene in chloroform suspension.

The compounds listed in Tables I and III, and those compounds in Table II for which no other method is noted, were prepared by this general procedure.

TABLE I

Aryl arylthionocarbamates, RNHC(S)OR′

R	R′	Yield, %	M.p., °C	Formula	C		H		Cl		N		S	
					Calc.	Found	Calc.	Found	Calc.	Found	Calc.	Found	Calc.	Found
3,4-Dichlorophenyl	Phenyl	44	156–157^a	$C_{13}H_9Cl_2NOS$	52.36	52.37	3.04	3.12	23.78	24.19	4.70	4.73	10.75	10.82
3,4-Dichlorophenyl	4-Methylphenyl	53	173–174^b	$C_{14}H_{11}Cl_2NOS$	53.86	53.63	3.55	3.84	22.71	22.83	4.49	4.62	10.27	10.18
3,4-Dichlorophenyl	4-Ethylphenyl	52	158–159^b	$C_{15}H_{13}Cl_2NOS$	55.22	55.37	4.02	4.13	21.74	21.76	4.29	4.34	9.83	10.02
3,4-Dichlorophenyl	4-*n*-Propylphenyl	74	159–161^b	$C_{16}H_{15}Cl_2NOS$	56.48	56.73	4.44	4.50	20.84	21.07	4.12	4.24	9.42	9.61
3,4-Dichlorophenyl	4-*n*-Butylphenyl	48	125–126^c	$C_{17}H_{17}Cl_2NOS$	57.63	57.39	4.84	4.84	20.01	20.13	3.95	4.17	9.05	9.18
3,4-Dichlorophenyl	2,6-di-*t*-Butyl-4-methylphenyl	24	139–140^c	$C_{22}H_{27}Cl_2NOS$	62.26	62.67	6.41	6.40	16.71	16.00	3.30	3.29	7.55	7.22
3,4-Dichlorophenyl	4-Methoxyphenyl	57	167–168^d	$C_{14}H_{11}Cl_2NO_2S$	51.24	50.97	3.38	3.43	21.61	21.61	4.27	4.42	9.76	9.62
3,4-Dichlorophenyl	4-Ethoxyphenyl	64	173–175^a	$C_{15}H_{13}Cl_2NO_2S$	52.64	52.46	3.84	3.92	20.72	20.73	4.09	4.45	9.37	9.48
3,4-Dichlorophenyl	3,4-Dichlorophenyl	91	142–143^a	$C_{13}H_7Cl_4NOS$	42.54	42.16	1.92	2.02	38.65	37.68	3.82	4.23	8.74	8.38
3,4-Dichlorophenyl	3-Nitrophenyl	85	135–136^b	$C_{13}H_8Cl_2N_2O_3S$	45.50	45.70	2.35	2.64	20.66	20.74	8.17	8.24	9.34	9.38
2,4-Dichlorophenyl	2,4-Dichlorophenyl	68	142–143^e	$C_{13}H_7Cl_4NOS$	42.54	42.77	1.92	2.10	38.65	38.85	3.82	4.23	8.74	8.38
4-Methoxyphenyl	4-Methoxyphenyl	87	175–176^b	$C_{15}H_{15}N_2O_3S$	62.26	62.44	5.23	5.34	—	—	4.84	4.85	11.08	11.05
4-Ethoxyphenyl	4-Ethylphenyl	61	118–119^b	$C_{17}H_{19}NO_2S$	67.75	67.43	6.35	6.41	—	—	4.65	4.64	10.63	10.56
3-Nitrophenyl	4-Ethylphenyl	58	104–105^b	$C_{15}H_{14}N_2O_3S$	59.58	59.66	4.67	4.62	—	—	9.27	9.13	10.60	10.49
3-Nitrophenyl	3-Nitrophenyl	67	157–158^f	$C_{13}H_9N_3O_5S$	48.90	49.24	2.84	3.09	—	—	13.16	13.06	10.04	10.13
3-Phenyl-6-hydroxyphenyl	4-Methoxyphenyl	57	139–140^a	$C_{20}H_{17}NO_3S$	68.36	68.28	4.88	5.12	—	—	3.99	4.18	9.12	9.41

[a] Crystallized from chloroform. [b] Chloroform – petroleum ether. [c] Petroleum ether. [d] Benzene – petroleum ether. [e] Ether – petroleum ether. [f] Benzene.

TABLE II

Aryl aralkylthionocarbamates, RNHC(S)OR′

R	R′	Yield, %	M.p., °C	Formula	C		H		Cl		N		S	
					Calc.	Found	Calc.	Found	Calc.	Found	Calc.	Found	Calc.	Found
Benzyl	Phenyl	46	82–83[b]	$C_{14}H_{13}NOS$	69.11	69.32	5.38	5.69	—	—	5.76	5.63	13.18	13.17
4-Nitrobenzyl	Phenyl	81	110–111[c]	$C_{14}H_{12}N_2O_3S$	58.32	58.36	4.20	4.32	—	—	9.72	9.65	11.12	11.15
4-Chlorobenzyl	Phenyl	82	119–120[d]	$C_{14}H_{12}ClNOS$	60.56	60.69	4.36	4.28	12.77	12.72	5.04	5.05	11.54	11.40
4-Chlorobenzyl	3,4-Dichlorophenyl	80	90–91[e]	$C_{14}H_{10}Cl_3NOS$	48.51	48.84	2.91	2.81	30.68	30.75	4.04	4.25	9.25	9.13
3,4-Dichlorobenzyl	Phenyl	89	104–105[c]	$C_{14}H_{11}Cl_2NOS$	53.85	53.98	3.55	3.70	22.71	22.48	4.49	4.31	10.27	10.06
3,4-Dichlorobenzyl	2-Methylphenyl	34[a]	89–90[b]	$C_{15}H_{13}Cl_2NOS$	55.25	55.14	4.02	4.41	21.75	21.94	4.29	4.32	9.83	9.90
3,4-Dichlorobenzyl	4-Methylphenyl	68[a]	118–119[b]	$C_{15}H_{13}Cl_2NOS$	55.25	55.08	4.02	4.10	21.75	21.60	4.29	4.17	9.83	9.75
3,4-Dichlorobenzyl	4-Ethylphenyl	59[a]	97–98[e]	$C_{16}H_{15}Cl_2NOS$	56.48	56.54	4.44	4.45	20.84	20.84	4.12	4.32	9.42	9.41
3,4-Dichlorobenzyl	4-*n*-Propylphenyl	14[a]	81[c]	$C_{17}H_{17}Cl_2NOS$	57.64	57.88	4.84	4.86	20.02	20.01	3.95	4.13	9.05	8.86
3,4-Dichlorobenzyl	4-*n*-Butylphenyl	42	90–91[b]	$C_{18}H_{19}Cl_2NOS$	58.70	58.53	5.20	5.36	19.25	19.35	3.80	3.91	8.71	8.69
3,4-Dichlorobenzyl	4-*n*-Hexylphenyl	49	87–88[e]	$C_{20}H_{23}Cl_2NOS$	60.61	60.81	5.85	6.24	17.89	17.81	3.53	3.63	8.09	8.38
3,4-Dichlorobenzyl	4-*n*-Decylphenyl	81	85–86[e]	$C_{24}H_{31}Cl_2NOS$	63.71	63.74	6.91	6.78	15.67	15.74	3.09	3.32	7.09	7.08
3,4-Dichlorobenzyl	4-*n*-Dodecylphenyl	70	87.5–88.5[c]	$C_{26}H_{35}Cl_2NOS$	64.48	64.81	7.34	7.33	14.76	14.96	2.91	3.10	6.67	6.67
3,4-Dichlorobenzyl	4-*n*-Octadecylphenyl	60	86–87[e]	$C_{32}H_{47}Cl_2NOS$	68.06	67.29	8.39	8.08	12.56	13.21	2.48	2.61	5.68	6.01
3,4-Dichlorobenzyl	2,6-di-*t*-Butyl-4-methylphenyl	65	113–114[b]	$C_{23}H_{29}Cl_2NOS$	63.01	62.92	6.67	6.67	16.17	16.22	3.19	3.03	7.31	7.26
3,4-Dichlorobenzyl	4-Methoxyphenyl	75	107–108[c]	$C_{15}H_{13}Cl_2NO_2S$	52.64	52.93	3.83	4.07	20.72	21.07	4.09	4.09	9.37	9.58
3,4-Dichlorobenzyl	4-Ethoxyphenyl	80	88–89[c]	$C_{16}H_{15}Cl_2NO_2S$	53.95	53.92	4.25	4.41	19.91	20.08	3.93	4.06	9.00	9.03
3,4-Dichlorobenzyl	3-Nitrophenyl	89	123–124[f]	$C_{14}H_{10}Cl_2N_2O_3S$	47.07	47.04	2.82	2.97	19.85	20.31	7.84	7.65	8.98	9.07
3,4-Dichlorobenzyl	β-Naphthyl	78	124–125[c]	$C_{18}H_{13}Cl_2NOS$	59.61	59.74	3.61	3.73	19.58	19.60	3.87	3.98	8.85	8.86
3,4-Dichlorobenzyl	4-Fluorophenyl	63	123–124[c,g]	$C_{14}H_{10}Cl_2FNOS$[h]	50.94	50.95	3.05	3.12	21.48	21.26	4.26	4.34	9.71	9.78
3,4-Dichlorobenzyl	4-Chlorophenyl	72	135–136[c]	$C_{14}H_{10}Cl_3NOS$	48.51	48.49	2.91	3.04	30.68	30.53	4.04	3.97	9.25	9.17
3,4-Dichlorobenzyl	2,4-Dichlorophenyl	85	154–155[c]	$C_{14}H_9Cl_4NOS$	44.13	44.13	2.38	2.55	37.23	37.46	3.68	3.70	8.41	8.26
3,4-Dichlorobenzyl	3,4-Dichlorophenyl	20	95–96[c]	$C_{14}H_9Cl_4NOS$	44.13	44.07	2.38	2.56	37.23	37.10	3.68	3.70	8.41	8.38
3,4-Dichlorobenzyloxy	Phenyl	50	67–68[b]	$C_{14}H_{11}Cl_2NO_2S$	51.22	51.39	3.38	3.13	21.60	21.78	4.27	4.29	9.77	9.87
2-(3,4-Dichlorophenyl)-ethyl	Phenyl	81	84–85[b]	$C_{16}H_{13}Cl_2NOS$	55.23	55.13	4.02	4.04	21.74	21.71	4.29	4.25	9.83	9.78
3-(3,4-Dichlorophenyl)-propyl	Phenyl	35	64–65[c]	$C_{16}H_{15}Cl_2NOS$	56.46	56.79	4.44	4.66	20.84	20.62	4.12	4.20	9.42	9.15

[a] Prepared by adding 3,4-dichlorobenzyl isothiocyanate to the appropriate phenol. [b] Crystallized from ether – petroleum ether. [c] Petroleum ether – chloroform. [d] Chloroform. [e] Petroleum ether. [f] Benzene. [g] Polymorphic modification, m.p. 108–109°. [h] Calc.: F, 5.76. Found: F, 5.73.

TABLE III

Aryl disubstituted thionocarbamates, RR′NC(S)OR″

R	R′	R″	Yield, %	M.p., °C	Formula	C Calc.	C Found	H Calc.	H Found	Cl Calc.	Cl Found	N Calc.	N Found	S Calc.	S Found
Phenyl	4-Chlorobenzyl	Phenyl	41	138–139[a]	$C_{20}H_{16}ClNOS$	67.87	67.99	4.56	4.59	10.02	10.00	3.96	4.08	9.06	8.92
4-Chlorobenzyl	4-Chlorobenzyl	Phenyl	34	114–115[b]	$C_{21}H_{17}Cl_2NOS$	62.70	62.82	4.26	4.34	17.63	17.67	3.48	3.46	7.97	7.90
4-Chlorobenzyl	4-Chlorobenzyl	β-Naphthyl	46	117–118[b]	$C_{25}H_{19}Cl_2NOS$	66.36	66.56	4.23	4.53	15.68	15.38	3.10	3.15	7.09	6.92
3,4-Dichlorobenzyl	3,4-Dichlorobenzyl	Phenyl	26	120–121[b]	$C_{21}H_{15}Cl_4NOS$	53.51	53.74	3.21	3.15	30.10	30.61	2.97	3.33	6.80	6.93

[a] Crystallized from acetone. [b] Acetone–water.

TABLE IV

Aralkyl aralkylthionocarbamates, RNHC(S)OR′

R	R′	Yield, %	M.p., °C	Formula	C Calc.	C Found	H Calc.	H Found	Cl Calc.	Cl Found	N Calc.	N Found	S Calc.	S Found
Benzyl	2,4-Dichlorobenzyl	84	107–108[a]	$C_{15}H_{13}Cl_2NOS$	55.22	55.16	4.02	4.08	21.74	22.22	4.29	4.14	9.83	9.51
3,4-Dichlorobenzyl	4-Chlorobenzyl	77	73–74[b]	$C_{15}H_{12}Cl_3NOS$	49.93	50.29	3.36	3.24	29.49	29.39	3.88	3.64	8.89	8.77
3,4-Dichlorobenzyl	2,4-Dichlorobenzyl	72	104–105[a]	$C_{15}H_{11}Cl_4NOS$	45.59	45.76	2.81	2.95	35.90	36.17	3.55	3.38	8.11	8.11
3,4-Dichlorobenzyl	3,4-Dichlorobenzyl	80	79–80[b]	$C_{15}H_{11}Cl_4NOS$	45.59	45.49	2.81	2.76	35.90	35.20	3.55	3.45	8.11	7.92

[a] Crystallized from acetone–water. [b] Ethanol–water.

Method B: 4-Methylphenyl 3,4-Dichlorobenzylthionocarbamate

A mixture of 3,4-dichlorobenzyl isothiocyanate (4.36 g, 0.02 mole), *p*-cresol (2.16 g, 0.02 mole), and triethylamine (0.04 g, 0.0004 mole) was heated in a sealed tube at 80° for 4 hours. The reaction mixture was dissolved in ether (100 ml) and the ether solution was washed with 2% sodium hydroxide solution and with water. The residue obtained on evaporation of the ether solution (5.8 g, m.p. 92–96°) was recrystallized from petroleum ether (40 ml) to give the product melting at 115–117°, yield 4.4 g (67.5%). One crystallization from ether - petroleum ether solvent raised the melting point to 118–119°. This reaction was found to be generally applicable to the addition of phenols to aralkyl isothiocyanates. Compounds prepared by this method are included in Table II.

Aralkyl Thionocarbamates

3,4-Dichlorobenzyl 3,4-Dichlorobenzylthionocarbamate

Sodium hydride (0.48 g of a 50% dispersion, 0.01 mole) was added to 3,4-dichlorobenzyl alcohol (1.77 g, 0.01 mole) in benzene (30 ml). The mixture was stirred at room temperature until the evolution of hydrogen ceased, after which it was briefly heated to boiling. The cooled suspension of sodium 3,4-dichlorobenzyloxide was treated with 3,4-dichlorobenzyl isothiocyanate (2.18 g, 0.01 mole) in benzene (10 ml) and the mixture was stirred overnight. The precipitated sodio derivative (4.18 g) was dissolved in acetone and the solution was filtered clear of insoluble impurities (0.34 g). Acidification of the filtrate with aqueous acetic acid precipitated the product (m.p. 103–104°), yield 2.86 g (72.1%). Recrystallization from aqueous acetone raised the melting point to 104–105°.

All of the compounds listed in Table IV were prepared by this procedure.

1,4-Phenylene Di-(3,4-dichlorobenzylthionocarbamate)

A mixture of 3,4-dichlorobenzyl isothiocyanate (2.18 g, 0.01 mole), hydroquinone (1.10 g, 0.01 mole), and triethylamine (0.01 g, 0.0001 mole) was heated in a sealed tube at 144° for 3 hours. The crude product was triturated in ether (100 ml) to give 1.79 g (65.6%) of product (m.p. 165–170°). Recrystallization from aqueous acetone raised the melting point to 170–171°, yield 1.25 g (45.8%). Anal. Calc. for $C_{22}H_{16}Cl_4N_2O_2S_2$: C, 48.38; H, 2.95; Cl, 25.96; N, 5.13; S, 11.74. Found: C, 48.49; H, 3.13; Cl, 25.98; N, 5.27; S, 11.73.

1,4-Phenylene Di-(benzylthionocarbamate)

A mixture of benzyl isothiocyanate (3.83 g, 0.026 mole), hydroquinone (1.41 g, 0.013 mole), and triethylamine (0.023 g, 0.0023 mole) was heated in a sealed tube at 144° for 3 hours. The crude product was extracted with ether, and the residue was recrystallized from aqueous acetone to give crystals melting at 171–172°, yield 0.24 g (4.6%). Recrystallization from acetone raised the melting point to 178–179°. Anal. Calc. for $C_{22}H_{20}N_2O_2S_2$: C, 64.67; H, 4.94; N, 6.86; S, 15.70. Found: C, 64.93; H, 5.07; N, 6.67; S, 15.79.

Aryl Thiolcarbamates

Phenyl chlorothiolformate (b.p. 90–95°/13 mm) was prepared in 18% yield by the method of Rivier (2).

The chlorothiolformate (3.40 g, 0.02 mole) in chloroform (30 ml) was added dropwise to a stirred solution of 3,4-dichlorobenzylamine (4.30 g, 0.04 mole) in chloroform (10 ml) at 25°. The reaction mixture was allowed to stand overnight, and the precipitated 3,4-dichlorobenzylamine hydrochloride (2.87 g, 100%) was recovered by filtration. The residue obtained on evaporation of the filtrate was crystallized from benzene - petroleum ether to give crystals melting at 101–102°, yield 2.65 g (55%).

TABLE V

Aryl N-substituted thiolcarbamates, RNHC(O)SR′

R	R′	Yield, %	M.p., °C	Formula	C		H		Cl		N		S	
					Calc.	Found	Calc.	Found	Calc.	Found	Calc.	Found	Calc.	Found
4-Chlorobenzyl	4-Chlorophenyl	82	192–193[a]	$C_{14}H_{11}Cl_2NOS$	53.85	53.98	3.55	3.68	22.71	22.73	4.49	4.54	10.27	10.02
3,4-Dichlorobenzyl	Phenyl	55	101–102[b]	$C_{14}H_{11}Cl_2NOS$	53.85	53.68	3.55	3.60	22.71	23.07	4.49	4.70	10.27	10.01
3,4-Dichlorobenzyl	4-Chlorophenyl	57	149–150[c]	$C_{14}H_{10}Cl_3NOS$	48.59	48.49	2.91	2.88	30.68	30.92	4.04	4.13	9.25	9.06
3,4-Dichlorophenyl	4-Chlorophenyl	70	209–210[d]	$C_{13}H_8Cl_3NOS$	46.94	47.20	2.42	2.45	31.98	32.23	4.21	4.43	9.64	9.58

[a] Crystallized from ethanol–water. [b] Benzene – petroleum ether. [c] Dioxane – petroleum ether. [d] Dioxane–water.

TABLE VI

Aryl chlorothionoformates, ROC(S)Cl

R	Yield, %	B.p., °C/mm Hg	Formula	C		H		Cl		S	
				Calc.	Found	Calc.	Found	Calc.	Found	Calc.	Found
4-Ethoxyphenyl	90.5	100–104/0.2	$C_9H_9ClO_2S$	49.89	49.67	4.19	4.01	16.36	16.27	14.80	14.48
4-Methylphenyl	92.0	62–65/0.25	C_8H_7ClOS	51.93	51.93	3.78	4.03	19.00	18.45	17.18	16.39
4-*n*-Propylphenyl	74.7	101–102/0.1	$C_{10}H_{11}ClOS$	55.94	56.07	5.16	5.00	16.52	16.62	14.93	14.70
4-Methoxyphenyl	84.8	96/0.4	$C_8H_7ClO_2S$	47.40	47.46	3.48	3.56	17.50	17.40	15.82	15.67
3-Nitrophenyl	54.0	128/0.1[a]	$C_7H_4ClNO_3S$[c]	38.63	39.36	1.85	2.16	16.29	15.90	14.73	14.18
4-Nitrophenyl	44.6	—[b]	$C_7H_4ClNO_3S$[d]	38.63	38.83	1.85	1.91	16.29	16.22	14.71	14.60

[a] M.p. 64–65°. [b] M.p. 59–60°. [c] Calc.: N, 6.44. Found: N, 6.39. [d] Calc.: N, 6.44. Found: N, 6.62.

4-Chlorophenyl chlorothiolformate (b.p. 145–155°/30 mm) was prepared in 67.5% yield from lead 4-chlorophenylmercaptide and phosgene, according to Rivier's method (2). Condensation with the appropriate amine as described above yielded the other thiolcarbamates listed in Table V.

S-*Methyl Phenylxanthate*

The reaction between carbon disulphide and potassium phenolate in ethanol (7) was found to yield only potassium ethylxanthate. Replacement of the ethanol by dimethylformamide yielded the desired potassium phenylxanthate.

Carbon disulphide (6.09 g, 0.08 mole) was added during a 30-minute period to potassium phenolate (10.58 g, 0.08 mole) in dimethylformamide (80 ml) at 20°. Methyl chloride was bubbled through the reaction mixture for 30 minutes at 30°. Water (1500 ml) was added, and the mixture was extracted with ether (5×100 ml). The ether extracts were combined and washed with 5% sodium hydroxide solution, 5% hydrochloric acid, and water. Fractionation of the dried ether solution yielded S-methyl phenylxanthate (b.p. 82–84°/0.11 mm, n_D^{25} 1.62189), yield 6.0 g (41.8%). Anal. Calc. for $C_8H_5OS_2$: C, 52.15; H, 4.38; S, 34.80. Found: C, 52.15; H, 4.45; S, 34.19.

Methyl 3,4-Dichlorobenzyldithiocarbamate

Method A.—3,4-Dichlorobenzylamine (2.58 g, 0.146 mole) was added to S-methyl phenylxanthate (2.7 g, 0.0146 mole) at room temperature. The temperature rose to 42°, and the mixture gradually solidified. Crystallization from chloroform – petroleum ether yielded methyl 3,4-dichlorobenzyldithiocarbamate (m.p. 98–100°), yield 3.37 g (74.1%). Recrystallization from chloroform – petroleum ether gave the analytical sample melting at 100–101°. Anal. Calc. for $C_9H_9Cl_2NS_2$: C, 40.61; H, 3.41; Cl, 26.64; N, 5.26; S, 24.08. Found: C, 41.11; H, 3.44; Cl, 26.07; N, 5.42; S, 24.14.

Method B.—Carbon disulphide (16.75 g, 0.22 mole) was added to a stirred mixture of sodium hydroxide (8.8 g, 0.22 mole) in water (14 ml) and 3,4-dichlorobenzylamine (35.21 g, 0.20 mole) in ether (100 ml) at 0–5°. The mixture was stirred for 1 hour at room temperature, and the sodium 3,4-dichlorobenzyldithiocarbamate (40.7 g, 75%) was recovered by filtration. The sodium salt (13.71 g, 0.05 mole) was added to a solution of methyl iodide (7.10 g, 0.05 mole) in methanol (150 ml) and the mixture was allowed to stand for 1 hour. The solution was concentrated and diluted with water, giving methyl 3,4-dichlorobenzyldithiocarbamate (m.p. 95–100°). Recrystallization from benzene yielded the pure product (9.0 g, 71%), melting point and mixed melting point with the product described above in A was 100–101°.

Methyl 3,4-Dichlorobenzylthionocarbamate

A solution of methyl 3,4-dichlorobenzyldithiocarbamate (1.33 g, 0.005 mole) in methanol (50 ml) was refluxed for 1 hour in the presence of Amberlite IRA-400 resin (25 ml) which had been saturated with phenol. The solution was filtered and evaporated. Crystallization of the residue from chloroform – petroleum ether yielded methyl 3,4-dichlorobenzylthionocarbamate (m.p. 75–76°), yield 0.60 g (48%). Anal. Calc. for $C_9H_9Cl_2NOS$: C, 42.23; H, 3.63; Cl, 28.35; N, 5.60; S, 12.82. Found: C, 42.23; H, 3.90; Cl, 28.60; N, 5.39; S, 12.59.

Ethyl 3,4-Dichlorobenzylthionocarbamate

The procedure is essentially that of Harris and Fischback (1). Methyl chloride was passed through a solution of potassium ethylxanthate (0.20 mole) in ethanol (200 ml) for 1 hour at 25–30°. 3,4-Dichlorobenzylamine (35.2 g, 0.20 mole) was added and the solution was maintained at 40° for 30 minutes. The solution was evaporated, and the residue was dissolved in chloroform (200 ml). The chloroform solution was extracted with 5% sodium hydroxide solution, 5% hydrochloric acid, and water. The chloroform solution was dried and evaporated to give ethyl 3,4-dichlorobenzylthionocarbamate (m.p. 55–58°), yield 16 g (30.3%). Anal. Calc. for $C_{10}H_{11}Cl_2NOS$: C, 45.46; H, 4.19; Cl, 26.84; N, 5.30; S, 12.14. Found: C, 45.39; H, 4.30; Cl, 27.00; N, 5.70; S, 12.10.

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