[CONTRIBUTION FROM THE RESEARCH LABORATORY OF THE GENERAL ELECTRIC COMPANY]

The Esterification of Tetrachlorophthalic Anhydride

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Previously reported methods of preparation of diesters of tetrachlorophthalic acid[1] have generally involved either the reaction of a metallic salt of the acid with an alkyl halide or sulfate or the reaction of tetrachlorophthalyl chloride[2] with a sodium alcoholate. Although tetrachlorophthalic acid readily forms monoesters on reaction with alcohols[1a,3,4,5] further esterification of the monoesters is apparently sterically hindered, as might be predicted from their structure.[3] The ready formation of monoester from tetrachlorophthalic acid may actually proceed through the intermediate formation of the anhydride, since Delbridge[6] found that tetrachlorophthalic acid hemihydrate was transformed into tetrachlorophthalic anhydride by such mild conditions as heating to 98°, crystallization from benzene or chloroform or vacuum drying over phosphorus pentoxide.

In the present work it has been found that the steric hindrance of the tetrachlorophthalic structure is not complete and that diesters can be obtained in appreciable yields by direct esterification of tetrachlorophthalic anhydride with primary alcohols. However, in all cases esterification proceeded much more slowly than with unchlorinated phthalic anhydride. Data on several new tetrachlorophthalates are listed in Table I. These esters probably all have the symmetrical structure because the diethyl tetrachlorophthalate obtained by esterification (m. p. 60°) resembled the diethyl ester (m. p. 60.5°) prepared from disilver tetrachlorophthalate[1b] and not the unsymmetrical diethyl ester (m. p. 126°) of Kirpal and Kunze.[2]

TABLE I

DIALKYL TETRACHLOROPHTHALATES

Tetrachlorophthalate	B. p., °C.	Mm.	$n^{25}D$	Sapon. equiv. Calcd.	Sapon. equiv. Found	Chlorine, % Calcd.	Chlorine, % Found	
Di-*n*-propyl	170–175	1	1.5348	194	197	36.54	36.0	
Diallyl[a]	Solid[b]			192	195	36.93	36.7	37.2
Di-*n*-butyl	180–185	1	1.5292	208	209	34.08	34.5	34.1
Di-n-amyl	191–195	0.4	1.5218	222	222	31.92	31.2	31.6
Di-*n*-hexyl	206–210	.1	1.5184	236	238	30.03	30.0	
Di-2-ethylhexyl[c]	216–225	.1	1.5130	264	265	26.85	26.8	26.5
Di-*n*-octyl	225–235	.1	1.5118	264	267	26.85	27.1	
Di-*n*-decyl	246–254	.2	1.5065	292	289	24.27	24.4	24.5

[a] First preparation by J. A. Loritsch in this Laboratory. [b] M. p. 74–74.5° (recryst. from petroleum ether). [c] First preparation by G. J. Bohrer in our laboratories.

At temperatures of 200° or higher the esterification reaction between tetrachlorophthalic anhydride and alcohols was accompanied by decarboxylation with the result that esters of 2,3,4,5-tetrachlorobenzoic acid[7] were also obtained. This decarboxylation reaction was found to be catalyzed by the addition of a small amount of potassium carbonate. In order to establish the structure of the compounds obtained in this way, tetrachlorobenzoates were also prepared from tetrachlorobenzoyl chloride. Data on several tetrachlorobenzoates are listed in Table II.

TABLE II

2,3,4,5-TETRACHLOROBENZOATES

Tetrachlorobenzoate[a]	M. p., °C.	Sapon equiv. Calcd.	Sapon equiv. Found	Chlorine, % Calcd.	Chlorine, % Found	
Methyl[b,c]	61.5–62.5	274	272	51.78	51.4	52.0
n-Propyl[c]	34	302	300	46.95	46.6	46.8
Allyl[b,c]	40–40.5	300	296	47.27	47.2	47.3
n-Butyl[c]	24–25	316	315	44.88	44.6	44.8
n-Amyl[c]	30–32	330	328	42.97	42.9	
n-Hexyl[b,c]	45–46.5	344	342	41.21	40.9	40.5
2-Ethylhexyl[b]	Oil[d]	372	369	38.12	38.1	37.7
n-Octyl[b,c]	35–35.5	372	373	38.12	37.4	
n-Decyl[b,c]	35.5–36	400	398	35.43	35.2	
Benzyl[c]	54–55	350	348	40.51	40.0	
2-Butoxyethyl[b]	Oil[e]	360	353	39.38	38.9	
2-Phenoxyethyl[b,c]	60.5–61.5	380	375	37.31	37.2	37.0

[a] Solids recrystallized from methyl alcohol or methyl alcohol plus ethyl acetate. [b] Compound obtained from high temperature, non-catalyzed esterification of tetrachlorophthalic anhydride. [c] Compound prepared from tetrachlorobenzoyl chloride. [d] B. p. 158–160° at 0.1 mm.; $n^{25}D$ 1.5364. [e] B. p. 160–165° at 0.1 mm.; $n^{25}D$ 1.5395.

In the preparation of 2,3,4,5-tetrachlorobenzoic acid from tetrachlorophthalic acid or anhydride.

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[1] (a) Dimethyl ester: Graebe, *Ann.*, **238**, 327 (1887); *ibid.*, **340**, 247 (1905); (b) diethyl ester: Graebe, *Ber.*, **16**, 861 (1883); *Ann.*, **238**, 326 (1887); (c) dicetyl ester: Meyer and Jugilewitsch, *Ber.*, **30**, 780 (1897); (d) dibenzyl ester: Meyer and Jugilewitsch, ref. 1c; (e) bis-(4-nitrobenzyl) ester: Meyer and Jugilewitsch, ref. 1c; Lyons and Reid, THIS JOURNAL, **39**, 1741 (1917).

[2] Kirpal and Kunze, *Ber.*, **62**, 2102 (1929), found that tetrachlorophthalyl chloride normally exists in the unsymmetrical form; however, symmetrical esters are generally obtained on reaction of the acid chloride with sodium alcoholates.

[3] V. Meyer and Sudborough, *ibid.*, **27**, 3146 (1894), obtained a small amount of dimethyl tetrachlorophthalate, as well as the monomethyl ester, by direct catalyzed esterification.

[4] Teterin and Zonis, *J. Gen. Chem.* (*U. S. S. R.*), **6**, 658 (1936); *cf. C. A.*, **30**, 6354 (1936).

[5] Rice, Jenkins and Harden, THIS JOURNAL, **59**, 2000 (1937).

[6] Delbridge, *Am. Chem. J.*, **41**, 393 (1909).

[7] Tust, *Ber.*, **20**, 2439 (1887).

the use of water as a reaction medium offered advantages over the use of acetic acid, employed by Tust.[7] It was also found that the addition of sodium hydroxide catalyzed the decarboxylation. By a proper choice of time-temperature conditions for the reaction it was possible to obtain either tetrachlorobenzoic acid or 1,2,3,4-tetrachlorobenzene[8] in good yield.

Approximate ionization constants ($K_1 = 5.5 \times 10^{-2}$ and $K_2 = 1.2 \times 10^{-3}$) for tetrachlorophthalic acid were calculated from data obtained by titration of the substance in dilute aqueous solution using the glass electrode. The ionization constant for monomethyl tetrachlorophthalate, similarly determined in dilute water–acetone solution, was about 2.2×10^{-2}.

Experimental

All melting points are corrected.

The tetrachlorophthalic anhydride used in this work was a commercial product[9]; m. p. 253–255°; neut. equiv. 143.5–144.5 (calcd. 142.9).

Ionization of Tetrachlorophthalic Acid.—Samples of tetrachlorophthalic acid hemi-hydrate[6] were dissolved in boiling distilled water. The solutions were cooled and titrated with sodium hydroxide using the Beckman *p*H meter. Data from two titrations are given in Table III. A plot of *p*H *vs.* ml. gave a smooth curve, indicating that K_1 and K_2 did not differ greatly. The ionization constants were calculated by an approximation method. First K_2 was calculated at the three-quarters neutralization point, assuming that the concentration of undissociated acid, H_2A, was negligible at this point. The concentrations, $[A^=]$ and $[HA^-]$, for the calculation were obtained from the following relationships: (a) $[H^+] + [Na^+] = [HA^-] + 2[A^=]$ ("principle of electrical neutrality") and (b) $[HA^-] + [A^=]$ = total tetrachlorophthalic–phthalate concentration. Values for K_1 were then determined at the zero, one-quarter and one-half neutralization points using this value of K_2. K_2 was then recalculated at the three-quarters point, using the average of these K_1 values to correct for the small concentration of undissociated acid at this point. Values for K_1 at the zero, one-quarter and one-half neutralization points were again determined using the new K_2 value. A third value of K_2 differed only slightly from the second value and the constants in Table III are from the second approximation.

TABLE III

TITRATION OF TETRACHLOROPHTHALIC ACID AT 27°

0.1046 *N* NaOH, ml.	*p*H	Total tetrachlorophthalic phthalate concn., moles/liter[a]	K_1	K_2
0.00	1.87	0.01564	0.049	
7.48	2.13	.01455	.050	
14.95	2.51	.01360	.052	
22.43	3.06	.01278		0.0012
0.00	1.88	.01473	.058	
7.04	2.14	.01376	.058	
14.08	2.52	.01290	.062	
21.11	3.07	.01217		.0012

[a] Initial volume 100 ml.

Ionization of Monomethyl Tetrachlorophthalate.[1a,3]—A mixture of 20 g. of tetrachlorophthalic anhydride and 100 ml. of methyl alcohol was boiled under reflux until solution occurred. The addition of water caused the separation of an oil which slowly crystallized.[10] Precipitated from toluene solution with petroleum ether, the product had m. p. 145–146° (dec., slow heating) and neut. equiv. 318.5 (calcd. 318). Data from two titrations of the substance using the Beckman *p*H meter are given in Table IV. In these titrations the sample was first dissolved in reagent grade acetone and then diluted to volume with boiled distilled water.

TABLE IV

TITRATION OF MONOMETHYL TETRACHLOROPHTHALATE AT 28°

0.1009 *N* NaOH, ml.	*p*H	Total tetrachlorophthalate concn., moles/liter[a]	*K*
0.00	2.42	0.00442	0.023
2.19	2.56	.00437	.022
4.38	2.72	.00432	.029
6.56	3.05	.00427	.022
0.00	2.21	.00792	.022
3.93	2.35	.00778	.022
7.85	2.54	.00763	.020
11.78	2.86	.00750	.020

[a] Initial volume 200 ml., containing 50 ml. of acetone.

2,3,4,5-Tetrachlorobenzoic Acid.—A mixture of 28.6 g. (0.1 mole) of tetrachlorophthalic anhydride and 200 ml. of water containing 4 g. (0.1 mole) of sodium hydroxide was placed in the glass liner of a small steel bomb and the sealed bomb was heated for seven hours in a 200°-oven. (The rate of heating was such that the bomb reached a temperature of 190° in two hours and 200° in four hours.) The crude product was worked up by solution in one liter of the dilute sodium hydroxide, filtration and precipitation with hydrochloric acid. There was obtained 24 g. (92.5%) of tetrachlorobenzoic acid of m. p. 194–195° and neut. equiv. 260 (calcd. 259.9). The product was recrystallized from acetone–water as needles having the same melting point.

When a mixture of 28.6 g. of tetrachlorophthalic anhydride and 200 ml. of water was heated in the bomb for three hours in a 250° oven, tetrachlorobenzoic acid was obtained in 93% yield. In this experiment the rate of heating was such that the bomb reached 215° in one hour, 245° in two hours and 250° in three hours.

Similar experiments with both tetrachlorophthalic acid hemihydrate and tetrachlorophthalic anhydride using acetic acid as reaction medium,[7] indicated that little decarboxylation occurred during six hours in the 200° oven or three hours in the 250° oven in this solvent.

1,2,3,4-Tetrachlorobenzene.—A mixture of 28.6 g. of tetrachlorophthalic anhydride and 200 ml. of water containing 4 g. of sodium hydroxide was heated in the bomb as above for three hours in the 250° oven. The alkali-insoluble product was obtained as light tannish crystals of m. p. 46–47°; yield 19.5 g. (90%). Recorded melting points for 1,2,3,4-tetrachlorobenzene are 45–46° and 47.5°.[8]

2,3,4,5-Tetrachlorobenzoyl Chloride.—A mixture of 70 g. of tetrachlorobenzoic acid and 100 ml. of thionyl chloride was boiled under reflux in a water-bath for one and one-quarter hours. After distillation of excess thionyl chloride, the residue was distilled under reduced pressure, giving 75 g. (99%) of 2,3,4,5-tetrachlorobenzoyl chloride, b. p. 99–101° at 0.2 mm.; m. p. 37–38°; sapon. equiv. 138 (calcd. 139).

Anal. Calcd. for C_7HOCl_5: Cl, 63.69. Found: Cl, 63.3.

Esters of 2,3,4,5-tetrachlorobenzoic acid were prepared

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[8] Beilstein and Kurbatow, *Ann.*, **192**, 238 (1878); Cohen and Hartley, *J. Chem. Soc.*, **87**, 1365 (1905); Holleman, *Rec. trav. chim.*, **39**, 741 (1920); Holleman and von Haeften, *ibid.*, **40**, 70 (1921).

[9] Niagara Alkali Company, Niagara Falls, N. Y.

[10] In all cases studied simple monoalkyl tetrachlorophthalates tended to precipitate as oils when water was added to their alcohol solutions.

from the acid chloride by reaction with excess alcohol in the presence of excess pyridine in the usual manner.

2,3,4,5-Tetrachlorobenzamide.—This compound, obtained from the reaction of the acid chloride with excess ammonium hydroxide, was recrystallized from acetone–alcohol as needles of m. p. 207–208°.

Anal. Calcd. for $C_7H_3ONCl_4$: Cl, 54.78. Found: Cl, 55.2.

2,3,4,5-Tetrachlorobenzanilide.—This compound, obtained from the reaction of the acid chloride with excess aniline, was recrystallized from alcohol as white crystals of m. p. 197–197.5°.

Anal. Calcd. for $C_{13}H_7ONCl_4$: Cl, 42.34. Found: Cl, 42.5.

Esterification of Tetrachlorophthalic Anhydride. (a) Acid-Catalyzed Reactions.—Using comparatively large amounts of sulfuric acid as catalyst, the dimethyl,[1a] diethyl,[1b] di-*n*-propyl and di-*n*-butyl esters of tetrachlorophthalic acid were obtained in low yields. The preparation of the dibutyl ester will serve to illustrate these preparations. A mixture of 143 g. (0.5 mole) of tetrachlorophthalic anhydride, 296 g. (4 moles) of *n*-butyl alcohol and 50 g. of concentrated sulfuric acid was boiled under reflux for five hours. The cooled reaction mixture was washed with 500 ml. of water. Excess 10% sodium carbonate solution was added and the mixture steam distilled to remove excess butyl alcohol. The oily layer was separated from the warm aqueous solution and distilled under reduced pressure. Di-*n*-butyl tetrachlorophthalate was obtained as a nearly colorless oil in 24% yield (50 g.).

The preparation of di-*n*-amyl tetrachlorophthalate was carried out using a smaller amount of sulfonic acid catalyst. A mixture of 572 g. (2 moles) of tetrachlorophthalic anhydride, 528 g. (6 moles) of *n*-amyl alcohol and 10 g. of *p*-toluenesulfonic acid monohydrate was placed in a 2-liter flask fitted with a thermometer, mechanical stirrer and 30-cm. unpacked, heated column connected to a distillation condenser. The mixture was stirred vigorously and heated by means of an electric mantle for twenty-nine hours; during this time the reaction temperature rose from 140 to 204°. About 126 ml. of distillate, containing 35 ml. of an aqueous layer, was collected. From the acidity of the reaction mixture it was calculated that 78% of diester had been formed. Excess alcohol was removed at 40–45 mm. The residue was stirred mechanically for twenty minutes at 50–60° with a solution of 100 g. (excess) sodium bicarbonate in one liter of water. The oily residue was then washed with one liter of water at 60°. Most of the emulsified water was removed from the hot mixture at 40 mm. The remainder of the water was removed by treatment with fuller's earth and potassium carbonate, the filter cake being washed with benzene. On distillation under reduced pressure diamyl tetrachlorophthalate was obtained as a yellowish oil in 71% yield.

The esterification of tetrachlorophthalic anhydride with allyl alcohol in the presence of acidic catalysts proved to be difficult. Several experiments, involving large excesses of allyl alcohol, extended reaction times, the use of benzene to carry off the water formed and various catalyst concentrations, gave diallyl tetrachlorophthalate in only 10–15% yields. Concurrent dehydration and polymerization reactions between the catalysts and allyl alcohol are believed to be responsible for these results.[11]

(b) Non-Catalyzed High-Temperature Reactions.—The reaction of tetrachlorophthalic anhydride with 2-ethylhexanol will serve to illustrate these reactions. A mixture of 572 g. (2 moles) of tetrachlorophthalic anhydride and 780 g. (6 moles) of 2-ethylhexanol was placed in a 2-liter flask fitted with a thermometer, gas inlet tube, sealed mechanical stirrer and 30-cm. heated column connected to a distillation condenser. Purified hydrogen was bubbled through the reaction mixture during the course of the reaction. The temperature of the column was controlled so that little excess alcohol was distilled but that the water (or azeotrope) was removed efficiently. The distillate was collected in a closed system and the effluent gases were passed through a calcium chloride tube and then through a tared Ascarite tube to absorb evolved carbon dioxide. The reaction mixture was heated by means of an electric mantle and constantly stirred. Table V summarizes the experimental data.

TABLE V

REACTION OF TETRACHLOROPHTHALIC ANHYDRIDE (2 MOLES) WITH 2-ETHYLHEXANOL (6 MOLES)

Total time, hours	Reaction temp., °C.	Acid no.[a]	Total H_2O, ml.	Total CO_2, g.
7	192–208	36	20	4.5
14	196–214	10	24	18.5
18	210–219	0.4	24	27.0

[a] Mg. potassium hydroxide required to neutralize 1 g. of reaction mixture.

From the amount of carbon dioxide evolved (27 g.) it was calculated that 31% of the tetrachlorophthalate had been transformed to tetrachlorobenzoate. Excess 2-ethylhexanol was distilled under reduced pressure, leaving 962 g. of residue. From its saponification equivalent (284) it was calculated that the residue contained 24 weight per cent. or 31 mole per cent. of 2-ethylhexyl tetrachlorobenzoate and 76 weight per cent. or 69 mole per cent. of di-2-ethylhexyl tetrachlorophthalate. Since the yield calculated on this basis was 960 g., the actual yield was essentially quantitative. The two products were separated by distillation under reduced pressure through a 30-cm. heated column. The first fractions obtained were washed with methyl alcohol to remove acidic impurities and then redistilled.

Similar results were obtained using *n*-hexyl, *n*-octyl and *n*-decyl alcohols in place of 2-ethylhexanol. In the case of hexyl alcohol less decarboxylation was observed.

(c) "Base-Catalyzed" High Temperature Reactions.—When a small amount of potassium carbonate was added to the reaction mixture, the rate of decarboxylation was increased and, as a result, the time necessary to obtain a neutral reaction mixture was decreased. Using the same apparatus and procedure as in (b) above, a mixture of 780 g. (6 moles) of 2-ethylhexanol, 572 g. (2 moles) of tetrachlorophthalic anhydride and 10 g. (0.0725 mole) of potassium carbonate was heated four and one-half hours at 193–203°. At the end of this time the reaction mixture was essentially neutral and 53 g. of carbon dioxide had been collected. From the amount of carbon dioxide involved it was calculated that 60% of the tetrachlorophthalate had been converted to tetrachlorobenzoate. Excess alcohol was distilled under reduced pressure and the residue (878 g.) was treated with fuller's earth and filtered. The saponification equivalent (312) indicated that the resulting oil contained 38 mole per cent. tetrachlorophthalate and 62 mole per cent. tetrachlorobenzoate.

Similar results were obtained with *n*-decyl alcohol.

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Summary

1. Although the di-esterification of tetrachlorophthalic anhydride is sterically hindered, dialkyl tetrachlorophthalates can be obtained by esterification procedures with primary alcohols.

2. At higher temperatures (200–220°) the esterification of tetrachlorophthalic anhydride is

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[11] Diallyl tetrachlorophthalate was obtained in better yield by the following methods: the reaction of allyl bromide with disilver tetrachlorophthalate or silver monoallyl tetrachlorophthalate; the reaction of allyl chloride with disodium tetrachlorophthalate or sodium monoallyl tetrachlorophthalate in aqueous solution at 100–120°.

accompanied by decarboxylation, esters of 2,3,4,5-tetrachlorobenzoic acid being obtained. This decarboxylation appears to be catalyzed by the addition of alkaline materials.

3. Several new esters of tetrachlorophthalic acid and 2,3,4,5-tetrachlorobenzoic acid have been prepared and improved syntheses have been developed for 2,3,4,5-tetrachlorobenzoic acid and 1,2,3,4-tetrachlorobenzene.

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[CONTRIBUTION FROM THE RESEARCH LABORATORY OF ENDO PRODUCTS, INC.]

N-Arylamides of Mercaptoacetic Acid. I. Analogs of α-Carbamylmercaptoacetanilide

BY ULRICH WEISS

The carbamyl compounds I have been prepared

$$\begin{gathered}\text{Ar—N(R)—CO—CH}_2\text{—S—X}\\ \text{I, X = —CONH}_2\\ \text{II, X = —H}\end{gathered}$$

as intermediates for making the desired N-arylmercaptoacetamides II.[1]

The known compounds of this type[2] have been obtained by interaction of an aromatic amine with thiocyanoacetic acid: $\text{Ar—NH}_2 + \text{COOH—CH}_2\text{—SCN} = \text{Ar—NH—CO—CH}_2\text{—S—CONH}_2$, this acid being usually generated during the reaction from chloroacetic acid and an alkali thiocyanate.[3] In a few instances, however, interaction of the base with the free acid in ether,[4] or, in the case of aniline, of the hydrochloride with sodium thiocyanoacetate in aqueous solution[5] has been used. This latter modification was found to be the most satisfactory one in our experiments.

In slightly acidic aqueous solution of molar equivalents of aromatic amine hydrochloride and sodium thiocyanoacetate, crystallization of compounds of type I usually starts at room temperature within a short time and gives in many cases (after about two days) yields up to 85–90% of the nearly pure compound.[6] Where results are less satisfactory, reaction of the base with thiocyanoacetate in dilute acetic acid may be advantageous.

The reaction seems quite general and characteristic for aromatic amines, only a small number of those tested proving unreactive,[7a] while none of a wide variety of non-aromatic amino-compounds gave a water-insoluble compound of type I.[7b]

As postulated by Rizzo,[8] the reaction appears to proceed through formation and subsequent isomerization of the thiocyanoacetate of the base. Such salts have actually been isolated from reaction of hydrazine and derivatives with free thiocyanoacetic acid in ether[4c] and found to rearrange readily to compounds of type I. In the experiments reported here, four such salts have been obtained from aqueous solutions. Three of them, derived from "unreactive" amines (cyclohexylamine, α-aminopyridine, 2-aminothiazole), failed to rearrange to compounds of type I. The salt of 2,6-dimethylaniline (*vic.-m*-xylidine) crystallized from an aqueous solution of the components, due to its low solubility. It rearranges to I ($\text{Ar—N(R)} = 2,6\text{-(CH}_3)_2\text{—C}_6\text{H}_3\text{—NH—}$) either in the dry state, or upon warming of its aqueous or alcoholic solutions, or if it is brought back into solution by dilution of the original reaction mixture. Solutions of the pure salt in water or organic solvents are stable at room temperature; the rapid formation of I in the original reaction mixture must therefore be due to some catalytic influence. No other salts of "reactive" amines were observed; attempts to prepare the aniline salt yielded only I ($\text{Ar—N(R)— = C}_6\text{H}_5\text{—NH—}$).

Experimental

Preparation of Carbamyl Compounds II, General Procedure.—A. In Aqueous Solution.—One-tenth mole of the base is suspended in 100 cc. of water, and brought into solution with the minimum amount of dilute hydrochloric acid; 0.1 mole = 15.7 g. of sodium thiocyanoacetate, $\text{NaOCO—CH}_2\text{—SCN·H}_2\text{O}$,[9] in about 10% aqueous solution is added. If the mixture is not acidic enough to give a slight bluish-gray color to congo paper, dilute hydrochloric acid is added; if the free base precipitates from the solution of its hydrochloride upon addition of the thiocyanoacetate, it is redissolved rapidly by addition of dilute hydrochloric acid (1:1), avoiding an excess. Crystalliza-

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[1] Paper II, Weiss, THIS JOURNAL, **69**, 2684 (1947).

[2] $\text{Ar—N(R)— = C}_6\text{H}_5\text{—NH—}$, $\text{C}_6\text{H}_5\text{—N(CH}_3\text{)—}$, $p\text{-Cl—C}_6\text{H}_4\text{—NH—}$, $o,m,p\text{-CH}_3\text{—C}_6\text{H}_4\text{—NH—}$, $2,4,5\text{-(CH}_3)_3\text{—C}_6\text{H}_2\text{—NH—}$, $\alpha,\beta\text{-C}_{10}\text{H}_7\text{—NH—}$, $p\text{-CH}_3\text{—O—C}_6\text{H}_4\text{—NH—}$, $p\text{-C}_2\text{H}_5\text{—O—C}_6\text{H}_4\text{—NH—}$, $\text{C}_6\text{H}_6\text{—NH—NH—}$, $\text{C}_6\text{H}_5\text{—N(CH}_3\text{)—NH—}$, $p\text{-CH}_3\text{—C}_6\text{H}_4\text{—NH—NH—}$. *Cf.* (a) Jaeger, *J. prakt. Chem.*, [2] **16,** 17 (1877); (b) Beckurts and Frerichs, *ibid.*, **66,** 172 ff (1902), and later papers by Frerichs, *et al.*; (c) Rheinboldt, Tappermann and Kleu, *ibid.*, **153**, 65 (1939).

[3] α-Halogenopropionic and butyric acids undergo analogous reactions.

[4] (a) Claesson, *Ber.*, **14,** 732 (1881); (b) Harries and Klamt, *ibid.*, **33,** 1154 (1900); (c) Frerichs and Foerster, *Ann.*, **371**, 229 ff. (1909).

[5] Ref. 2b, p. 173; *cf.* the analogous reaction of α-thiocyanopropionic acid: Fredga, *J. prakt. Chem.*, [2] **123,** 110 (1929).

[6] The smooth formation of a —CO—NH— bond under such mild conditions is certainly remarkable.

[7] (a) Unreactive aromatic amines: *o*-nitraniline, 2-aminoresorcinol, diphenylamine, sulfanilic acid; (b) non-aromatic amino compounds tested: hydroxylamine, urea, thiourea, acetamidine, glycine, glycine ethyl ester, glutamic acid, cyclohexylamine, α-amino-pyridine, 2-amino-thiazole. The unidentified product obtained from semicarbazide is not of type I; see experimental part. It may be of interest that all reactive compounds are aromatic amines (or hydrazines) with *pK*-values between about 10^{-9} and 10^{-12}. The unreactive *o*-nitraniline, *e. g.*, differs from its reactive isomers by $pK \approx 10^{-14}$ against $\approx 10^{-12}$.

[8] Rizzo, *Gazz. chim. ital.*, **28, I,** 360 (1893).

[9] Prepared by the method of Claesson, *Ber.*, **10**, 1347 (1877).