[CONTRIBUTIONS FROM THE SHEFFIELD LABORATORY OF YALE UNIVERSITY.]

RESEARCHES ON THIOCYANATES AND ISOTHIOCYANATES.

(FOURTH PAPER.)

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THE work described in this paper was undertaken with the object of investigating the behavior of some tertiary halides towards alcoholic solutions of potassium thiocyanate. Up to the present time no tertiary alkyl halide has been found to give an isothiocyanate or mustard oil. This property has only been observed in the case of the primary allyl halides and the secondary diphenylmethyl bromide. In fact this subject has hitherto received little attention. Of the three tertiary halides that have been examined triphenylmethyl bromide and α-bromisobutyric ethyl ester gave normal thiocyanates while tricarbethoxymethane failed to react.[1]

The tertiary halides which we now discuss comprise all the possible compounds formed by substituting the positive group methyl, and the negative radicals, phenyl and carbethoxyl, —$CO.OC_2H_5$, for hydrogen in methyl bromide.[2] There are ten combinations to be considered; and among these, it will be noticed, are the above three tertiary forms that have already been examined:

I. $BrC(CH_3)_3$
II. $BrC(CH_3)_2C_6H_5$
III. $BrCCH_3(C_6H_5)_2$
IV. $BrC(C_6H_5)_3$
V. $BrC(CH_3)_2CO_2C_2H_5$
VI. $BrCCH_3(CO_2C_2H_5)_2$
VII. $BrC.CH_3.C_6H_5.CO_2CH_3$
VIII. $BrC(CO_2C_2H_5)_3$
IX. $BrCC_6H_5(CO_2C_2H_5)_2$
X. $ClC(C_6H_5)_2CO_2C_2H_5$

The investigation has shown that six of these compounds give normal thiocyanates, while the remaining four give neither normal or isothiocyanates.

Tertiary butyl bromide (I) reacted smoothly with alcoholic

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[1] Since the above was written Crocker has found that picryl chloride gives an isothiocyanate. *Jour. Chem. Soc.* (London), **81**, 436 (1902).

[2] In one case (VII) the methyl ester was used and in another (X) the chloride instead of the bromide was employed; experience has shown that the bromides react more readily than the chlorides.

potassium thiocyanate, and the product was shown to be a normal thiocyanate by combining it with thioacetic acid, whereupon acetyl dithioisobutyl urethane, $CH_3CONHCSSC_4H_9$, was obtained.

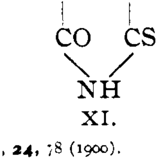
1'-Bromisopropyl benzene (II), 1'-brom-1,1-diphenylethane, (III), 1'-bromhydratropicmethyl ester (VII), and tricarbethoxymethyl bromide (VIII) reacted readily with, or were decomposed by, potassium thiocyanate, and a bright yellow, amorphous precipitate separated which had the properties of the so-called pseudocyanogen sulphide. These bromides therefore act like free bromine on potassium thiocyanate. The behavior of tricarbethoxymethyl bromide, in reacting immediately in the cold, is in strong contrast to that of the chloride, which showed little tendency to react even on heating for a number of hours.

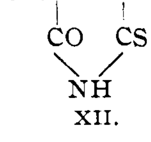
Triphenylmethyl bromide (IV), as previously stated, gave a normal thiocyanate. In this case the rhodanide formed thiol esters with thioacetic and thiobenzoic acids.

α-Bromisobutyric ethyl ester (V) also gave a normal thiocyanate. This was shown by boiling the product with hydrochloric acid, whereupon α-μ-diketo-β-dimethyltetrahydrothiazole,[1] was obtained.

Methylbrommalonic ester (VI) readily reacted with potassium thiocyanate, while ethyl chlormalonic ester remained unaltered even when heated with potassium thiocyanate to 140°-145° for a number of hours. When the product, in the case of methylbrommalonic ester was warmed with thioacetic acid, a thick oil was obtained which, on dissolving in alkali and precipitating with hydrochloric acid, gave α-keto-μ sulpho-β-methylthiazolidine, the so-called α-rhodaninpropionic acid.[2] The structure of this is represented by formula XI. That the rhodanide is a normal thiocyanate is shown by the fact that the reaction took place as follows:

$$CH_3CONHCSSCCH_3(CO_2C_2H_5)_2 + NaOH + H_2O = C_4H_5ONS_2 + CH_3COONa + CO_2 + 2C_2H_5OH.$$


XI.


XII.

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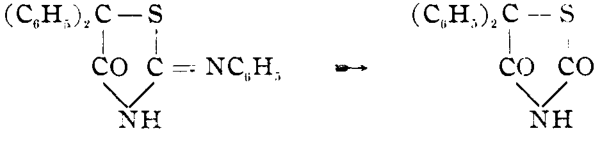
[1] *Am. Chem. J.*, **24**, 78 (1900).

[2] Berlinerblau: *Ber. d. chem. Ges.*, **19**, 125.

Bromphenylmalonic ester (IX) reacted smoothly with potassium thiocyanate, and the product with thioacetic acid and alkali behaved in a similar manner, inasmuch as α-keto-μ-sulpho-β-phenylthiazolidine (XII) was obtained.

Diphenylchlorethyl acetate (X) gave the first and only rhodanide that has failed to react with thio acids. It reacted, however, with aniline, yielding triphenylpseudothiohydantoïn (XIII). On warming the latter with alcoholic hydrochloric acid, α-μ-diketo-β-diphenyl tetrahydrothiazole was obtained (XIV).



XIII. XIV.

The behavior of this hydantoïn with hydrochloric acid differs from that of the pseudothiohydantoïn from phenylthiocyanethyl acetate,[1] inasmuch as the latter, under certain conditions, gives up ammonia and not aniline on boiling with hydrochloric acid; generally, however, a mixture is obtained. The behavior of phenylpseudothiohydantoïn with hydrochloric acid has been supposed to show that the compound has the structure represented by formula XVII.

We have found that this long-known phenylpseudothiohydantoïn which, according to Meyer,[2] Liebermann,[3] and Dixon,[4] gives α,μ-diketo-N-phenyltetrahydrothioazole ("phenylsenfoelglycolid"), formula XXI, with hydrochloric acid, also gives α,μ-diketotetrahydrothiazole (XX). It follows from this that the reaction with hydrochloric acid can not be used to decide the structure of these thiohydantoïns. Both of the theoretically possible isomeric phenylpseudothiohydantoïns, (XVII) and (XVIII), for example, can give phenylthiohydantoic acid (XIX), and this can be decomposed into the two tetrahydrothiazoles that are actually obtained:

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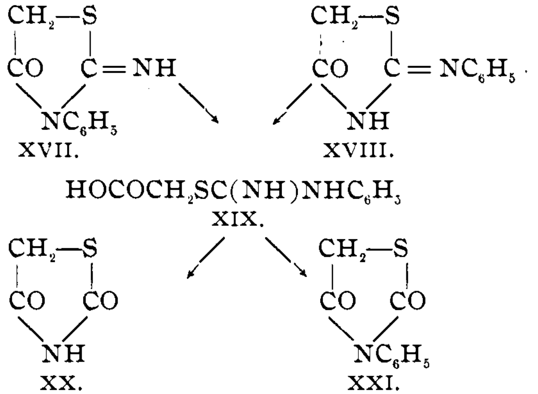
[1] *Am. Chem. J.*, **26**, 353 (1901).

[2] *Ber. d. chem. Ges.*, **14**, 1661 (1881).

[3] *Ann. Chem.* (Liebig), **207**, 129 (1881).

[4] *J. Chem. Soc.* (London), **71**, 620 (1897).



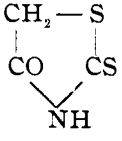
XVII. XVIII.

$HOCOCH_2SC(NH)NHC_6H_5$

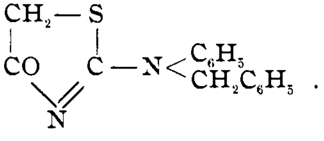
XIX.

XX. XXI.

Dixon found that the hydantoïn in question gave α-keto-μ-sulphotetrahydrothiazole ("rhodanininsäure"), formula, XXII below, when heated with carbon disulphide, and he therefore assigned to the compound the structure represented above by formula XVIII. This is undoubtedly correct since by the action of benzyl chloride and alkali, a benzyl derivative is obtained from this hydantoïn, which is identical with that from benzylphenylthiourea, $C_6H_5(C_6H_5CH_2)NCSNH_2$, ethylchloracetate and alkali. This benzyl derivative must have the structure represented by formula XXIII:



XXII.



XXIII.

EXPERIMENTAL PART.

I.—*Tertiary Butyl Bromide* $(CH_3)_3CBr$, *and Potassium Thiocyanate.*—The bromide was made by the union of isobutylene and hydrogen bromide. The purified material reacted immediately when warmed with an alcoholic solution of potassium thiocyanate, and potassium bromide separated. The product was an oil which possessed a strong, pungent odor. It could not be distilled under reduced pressure without decomposition and therefore, for analysis, it was simply washed and dried in a desiccator over sulphuric acid. A nitrogen determination then gave:

	Calculated for C_5H_9NS.	Found.
Nitrogen	12.17	12.48

Tertiary Butyl Rhodanide and Thioacetic Acid.—Eight grams of the rhodanide and 6 grams of thioacetic acid were heated on the water-bath in benzene for eight hours. On cooling, a white flocculent precipitate separated. This crystallized from benzene in scales or plates, and did not melt at 260°. It was extremely soluble in alcohol, contained nitrogen but no sulphur, and was soluble in a solution of sodium hydroxide. A sufficient amount of this was not obtained for identification. Two determinations gave 10.88 and 11.01 per cent. nitrogen. The oil that remained, after evaporating the benzene, solidified on cooling; it was dissolved in dilute sodium hydroxide and the solution shaken with ether. From the alkaline solution acetic acid precipitated a bright yellow body which, on crystallizing from petroleum ether, melted at 112°-113°. Its solubility in sodium hydroxide, its yellow color and the following nitrogen determination show that this material is *tertiary butylacetyldithiocarbamate*, $CH_3CONHCS.SC(CH_3)_3$.

	Calculated for $C_7H_{13}ONS_2$.	Found.
Nitrogen	7.33	7.32

II.—1'-*Bromisopropyl Benzene*, $C_6H_5CBr(CH_3)_2$, *and Potassium Thiocyanate.*—Isopropyl benzene was prepared from normal propyl chloride and benzene by means of the Friedel-Crafts reaction. The material used boiled at 152°-154° at ordinary pressure. Eight grams of the hydrocarbon were brominated at 115°-120° with the calculated quantity of bromine. The product was washed thoroughly with a solution of sodium carbonate, extracted with ether, and dried in a vacuum. It was impossible to purify this new bromide by distilling under diminished pressure since an attempt at 16 mm. resulted in rapid decomposition taking place at about 135°, with evolution of hydrogen bromide. A bromine determination agreed with the calculated, probably as closely as could be expected.

	Calculated for $C_9H_{11}Br$.	Found.
Bromine	40.20	38.10

This bromide immediately reacted with potassium thiocyanate in warm alcohol, and a fine yellow powder separated. The latter possessed all the properties of *pseudocyanogen sulphide.* The material remaining in the alcoholic solution proved to be an oil but not enough of this was obtained to establish any definite boiling-point.

III.—*1',1'-Diphenyl-1'-Bromethane,* $(C_6H_5)_2CBrCH_3$, *and Potassium Thiocyanate.*—Diphenylethane was prepared from ethylidine chloride (from paraldehyde and phosphorus pentachloride) and benzene by means of the Friedel and Crafts reaction. It was found that this hydrocarbon could not be brominated in the usual manner for the preparation of other halogen derivatives of benzene in the side-chain, owing to the ease with which the bromide loses hydrogen bromide. After several unsuccessful attempts it was found that a product consisting essentially of the desired bromide could be prepared by brominating the hydrocarbon at 100°-105°. The product, washed with sodium carbonate and water and dried in a vacuum desiccator, gave the following result on analysis:

	Calculated for $C_{14}H_{13}Br$.	Found.
Bromine	30.6	24.37

When a product thus prepared was distilled at 10 mm. pressure, it rapidly decomposed with evolution of hydrogen bromide. On continuing the distillation, it practically all boiled at 155°-165°. Diphenylethylene boils at 162° at 15 mm. pressure, according to Anschütz.[1] The crude bromide reacted at once with potassium thiocyanate in alcohol, *pseudocyanogen sulphide* separated, and an oil was obtained that boiled at 150°-162° at 11 mm. pressure. (Diphenylethylene?)

IV.—*The Action of Triphenylmethyl Bromide on Potassium Thiocyanate,* which resulted in the formation of a normal thiocyanate, was described in our second paper.[2]

V.—*Ethyl-α-Bromisobutyric Ester Gave Ethylnormalthiocyanisobutyrate,*[3] as shown in this laboratory by Mr. Le B. Gray. The thiocyanate reacts normally with thiobenzoic acid, and *benzoyldithioethyl-α-isobutyrate carbonate,*

$$C_6H_5CONHCS.SC(CH_3)_2CO_2C_2H_5,$$

is formed. This separates from a mixture of benzene and petro-

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[1] *Ann. Chem.* (Liebig), **235**, 159.

[2] *Loc. cit.*

[3] *Loc. cit.*

leum ether in the form of yellow prisms, which melt at 113°-114°. It is extremely soluble in alcohol.

	Calculated for $C_{11}H_{17}O_3NS_2$.	Found.
Nitrogen	4.50	4.37

VI.—*Brommethylmalonic Ethyl Ester,* $CH_3CBr(CO_2C_2H_5)_2$, *and Potassium Thiocyanate.*—Methylmalonic ester was brominated at 65°; the product practically all boiled at 112°-118° at 14 mm. pressure. A bromine determination in a portion of this boiling at 114° gave 31.6 per cent. while the calculated is 31.62 per cent. bromine.

When this bromide was mixed in alcohol with potassium thiocyanate it immediately began to react. The mixture was warmed for about a half hour, on the steam-bath, and then water precipitated an oil possessing a strong penetrating odor. It all boiled at 139°-142° at 9 mm. pressure; a portion boiling at 140° was analyzed with the following result:

	Calculated for $C_9H_{13}O_4NS$.	Found.
Nitrogen	6.06	6.15

Five grams of this rhodanide, 2 grams of thioacetic acid and 10 cc. of benzene were heated on the water-bath for twelve hours. After evaporating the benzene, an oil was obtained which would not solidify in a freezing-mixture. The oil dissolved in a dilute solution of sodium hydroxide and was not precipitated with carbon dioxide; dilute acetic acid, on the other hand, precipitated a yellow solid which was purified by crystallizing from alcohol and benzene. It then formed plates which melted at 124° and showed no effervescence when heated to 175°. Nitrogen determinations agreed with the calculated for *α-keto-μ-sulpho-β-methylthiazolidine:*

	Calculated for $C_4H_5ONS_2$.	Found. I.	Found. II.
Nitrogen	9.52	9.28	9.58

In fact this compound is identical with the so-called "α-rhodaninpropionsäure" of Berlinerblau[1] which was obtained from chlorpropionic acid and ammonium thiocyanate. Berlinerblau gives the melting-point at 123°.

VII.—*α-Bromhydratropicmethyl Ester,* $CH_3CBr(C_6H_5)CO_2CH_3$, *and Potassium Thiocyanate.*—Although the preparation of hydra-

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[1] *Ber. d. chem. Ges.*, **19**, 123.

tropicmethyl ester, by the method which we adopted, includes ten stages, nevertheless the brom-derivative can be more easily obtained, in quantity, by the following procedure than by the method which involves the preparation of atrolactinic acid. On the other hand, a purer product is undoubtedly obtained by the action of hydrogen bromide on atrolactinic acid.[1]

Starting with benzyl chloride we prepared the cyanide, phenylacetic acid, the ethyl ester, and from the latter phenyloxalaceticethyl ester[2] which gave phenylmalonic ester. Eighty grams of this were prepared boiling at 159.5°-160° at 12 mm. pressure. This was methylated[3] and 60 grams of phenylmethylmalonic ester resulted, which boiled at 12 mm. pressure at precisely the same point as the unaltered material. On saponifying this, 21 grams of methylphenylmalonic acid were obtained, melting at 155°-156°. When this was heated and the resulting hydratropic acid was esterified, 13 grams of methyl ester were obtained, which boiled at 218°-221° at ordinary pressure Neure[4] gives the boiling-point of this ester at 221°. The bromination of this was conducted in an oil-bath at 150°. The dark-colored product was washed with water and sodium carbonate and an attempt was made to purify a portion by distilling under diminished pressure, whereupon it was found that the oil underwent decomposition, giving off hydrogen bromide. The washed product was therefore warmed directly with an alcoholic solution of potassium thiocyanate (through an oversight no portion of the oil was reserved for analysis). The products of the reaction consisted of *pseudocyanogen sulphide* and an oil. The latter, since it was not a rhodanide, was not examined.

VIII.—*Tricarbethoxymethyl Bromide, $C.Br(CO_2C_2H_5)_3$, and Potassium Thiocyanate.*—Tricarbethoxymethane was easily brominated on the water-bath and the product boiled, for the most part, at 162°-163° at 16 mm. pressure. The colorless oil thus obtained was analyzed with the following result.

	Calculated for $C_{10}H_{15}O_6Br$.	Found.
Bromine	25.7	25.5

When this bromide was warmed in alcohol with potassium thio-

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[1] Fittig and Kast: *Ann. Chem.* (Liebig), **206**, 28 (1881).

[2] Wislicenus: *Ber. d. chem. Ges.*, **27**, 1093.

[3] Wislicenus and Goldstein: *Ibid.*, **28**, 815.

[4] *Ann. Chem.* (Liebig), **250**, 152.

cyanate, it reacted at once and *pseudocyanogen sulphide* separated. On adding water to the alcoholic solution an oil was obtained. This was distilled at 10 mm. pressure and although there was no apparent decompositon, during the distillation, it started to boil at about 141° and continued up to 177°. The bromide therefore reacts with potassium thiocyanate with decomposition.

IX.—*Phenylbrommalonicethyl Ester,* $C_6H_5C.Br(CO_2C_2H_5)_2$, *and Potassium Thiocyanate.*—This bromide was obtained by brominating phenylmalonicethyl ester at 140°-150°. It formed a colorless oil which was found to boil at 192° at 20 mm. pressure and, from another preparation, at 177°-181° at 11 mm. pressure. A bromine determination in the first case gave:

	Calculated for $C_{13}H_{15}O_4Br$.	Found.
Bromine	25.38	24.98

When this bromide was treated with potassium thiocyanate an oil was obtained which could not be purified by distilling under diminished pressure. At 20 mm. rapid decomposition took place at about 200°. The oil, after washing with water and drying, was analyzed with the following result:

	Calculated for $C_{14}H_{15}O_4NS$.	Found.
Nitrogen	4.77	5.37

The nitrogen determination agrees, perhaps as well as could be expected, for a non-rectified oil, with the calculated for *thiocyanphenylmalonicethyl ester,* $C_6H_5C(SCN)(CO_2C_2H_5)_2$.

Ten grams of this rhodanide and 3 grams of thioacetic acid were heated in benzene for twenty-four hours, whereupon, on evaporating the benzene, an oil was obtained which refused to solidify. It was dissolved in cold dilute sodium hydrate and, after standing, was precipitated with dilute hydrochloric acid. This treatment gave a yellow solid, which, on crystallizing from alcohol, formed yellow prisms and melted at 178°-179° without effervescence. A nitrogen determination agreed with the calculated for *α-keto-μ-sulpho-β-phenylthiazolidine:*

	Calculated for $C_9H_7ONS_2$.	Found.
Nitrogen	6.69	6.51

Thiocyanmethylmalonic ester and thiocyanphenylmalonic ester therefore behave in an analogous manner with thioacetic acid and alkali. The reaction proves that these rhodanides are normal thiocyanates.

X.—*Diphenylchloraceticethyl Ester,* $(C_6H_5)_2C.Cl.CO_2C_2H_5$, *and Potassium Thiocyanate.*—The chlorester was made by treating benzilic acid with phosphorus pentachloride and then pouring the acid chloride into cold alcohol.[1]

When this chloride was warmed in alcoholic solution with potassium thiocyanate for about five hours the reaction was complete. On evaporating, an oil was obtained which had a most remarkable behavior on heating. On attempting to distil under reduced pressure no signs of decomposition could be observed, but no matter at what rate the distillation was conducted it frothed over in one continuous stream, and no fractionation could be accomplished. A nitrogen determination was therefore made in a sample of crude product that was washed and dried over sulphuric acid.

	Calculated for $C_{17}H_{15}O_2NS$.	Found.
Nitrogen................	4.7	4.2

This rhodanide is distinguished from all others that have been examined by the fact that it does not react with thioacetic or thiobenzoic acids, on warming in benzene for the usual length of time (two to twenty-four hours).

The oil, recovered from the treatment with thiobenzoic acid, was heated with aniline on the steam-bath for from five to six hours. On washing the product with dilute hydrochloric acid and crystallizing from alcohol, colorless prisms were obtained which melted at 250°. This, on analysis, gave the following result which agrees with the calculated for *triphenylpseudothiohydantoin.*

	Calculated for $C_{21}H_{16}ON_2S$.	Found.
Nitrogen................	8.13	8.14

When this substance was dissolved in alcohol and warmed for a short time with concentrated hydrochloric acid, a product was obtained which crystallized from dilute alcohol in colorless prisms and melted at 144°-145°. An examination of the acid solution showed that aniline had been removed by this treatment and the

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[1] Bickel: *Ber. d. chem. Ges.*, **22**, 1537.

crystalline material gave results agreeing with the calculated for *α-μ-diketo-β-diphenyltetrahydrothiazole:*

	Calculated for $C_{15}H_{11}O_2NS$.	Found.
Nitrogen	5.20	5.24

In our second paper on thiocyanates it was shown that ethyl phenylthiocyanacetate reacts with aniline, giving a compound that was considered to be diphenylpseudothiohydantoïn. We now find that ethylphenylchloracetate and phenylthiourea give the same compounds. This proves that these compounds are pseudothiohydantoïns. On boiling the compound from phenylthiourea with 30 per cent. hydrochloric acid a compound was obtained that crystallized from alcohol in needles and melted at 173°-174°. A nitrogen determination agreed with the calculated for *α-μ-diketo-β-phenyl-N-phenyltetrahydrothioazole:*

	Calculated for $C_{15}H_{11}O_2NS$.	Found.
Nitrogen..............	5.20	5.44

Benzylphenylpseudothiohydantoïn.—This was obtained by warming 5.5 grams of phenylpseudothiohydantoïn, 6.5 grams of sodium dissolved in 55 cc. of alcohol and 20 cc. of water, and 3.6 grams of benzyl chloride, until the mixture no longer gave an alkaline reaction. When the alcohol was evaporated, the residue taken up in ether and shaken with alkali, and the product crystallized from alcohol, beautiful, colorless, transparent, square tables were obtained which melted at 124°-125°.

The same compound was obtained by warming 4 grams of unsymmetrical benzylphenylthiourea and 3 grams of ethyl chloracetate, in alcoholic solution, for a number of hours. The alcohol was then evaporated and the residue treated with alkali. On crystallizing from alcohol, square tables melting at 124°-125° resulted and when mixed with the above preparation the melting-point was not altered.

Dixon prepared this benzylphenylpseudothiohydantoïn, by a different method. He states that it melts at 118°-119° (corr.).

NEW HAVEN, CONN.,
April 8, 1902.