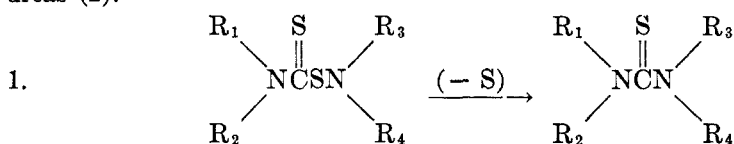


OXIDATIVE CONDENSATION REACTIONS OF AMINES WITH
CARBIDITHIOATES AND XANTHATES¹

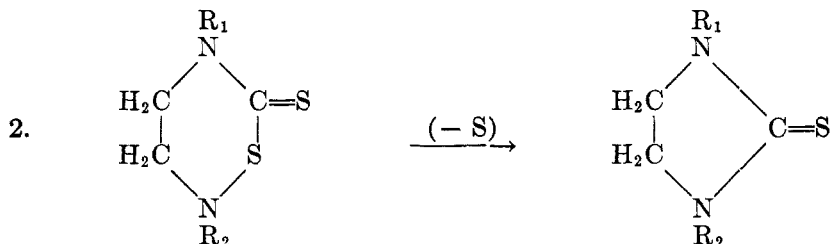
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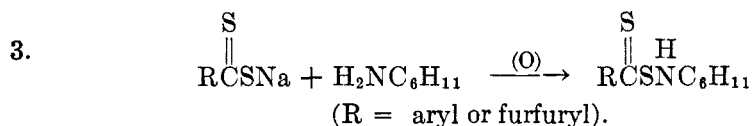
Thioamides or disulfides were found to be the products of the oxidative condensation of the sodium salts of carbidithioates and cyclohexylamine. These results contrast with those obtained by ourselves and others and discussed in the first paper of this series, that oxidative condensation of amines with mercaptothiazoles and thiazolines resulted in the formation of thiazole- and thiazoline-sulfenamides (1). Later it was discovered that the oxidation of dithiocarbamate-amine mixtures produced thiocarbamylsulfenamides (2) and this work was extended to the formation of cyclicsulfenamides (6-thiotetrahydro-1,2,5-thiadiazines) from the inner salts of N-alkyl-N-(β-alkylaminoethyl)dithiocarbamic acids (3). In the course of this earlier work it was discovered that the thiocarbamylsulfenamides more or less readily lost sulfur forming thioureas (2).



Similarly the tetrahydro-1,2,5-thiadiazines lost sulfur on heating, the cyclic thioureas (imidazolidines) being formed.



It is suggested that thioacylsulfenamides were the initial products of the oxidative condensation of sodium carbidithioates and cyclohexyl amine.



These thioacylsulfenamides were then unstable and decomposed immediately with loss of sulfur and the formation of thioamides.

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The use of chloroamines as intermediates in the synthesis of sulfenamides, which was successfully used for the preparation of thiocarbamyl- and thiazole-sulfenamides (2), did not yield the expected sulfenamides from carbidithioates. The reaction of N-monochlorocyclohexylamine and sodium dithiofuroate yielded N-cyclohexylthiofuramide. Here also the sulfenamide was probably an intermediate product of the reaction.

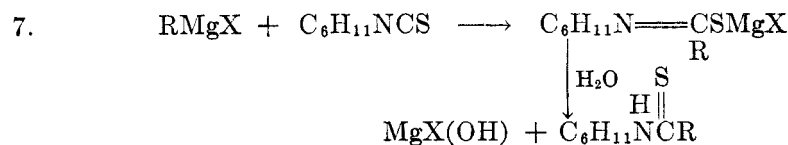
Oxidation of a mixture of cyclohexylamine and sodium monothiobenzoate produced an oxygen amide.



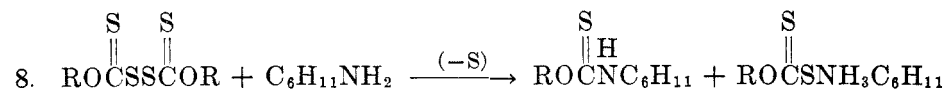
The benzoylsulfenamide was probably formed but lost sulfur immediately to form the amide.



These thioamides are not reported in the literature and were identified in several cases by synthesis from the appropriate Grignard reagents and cyclohexyl isothiocyanate (4).



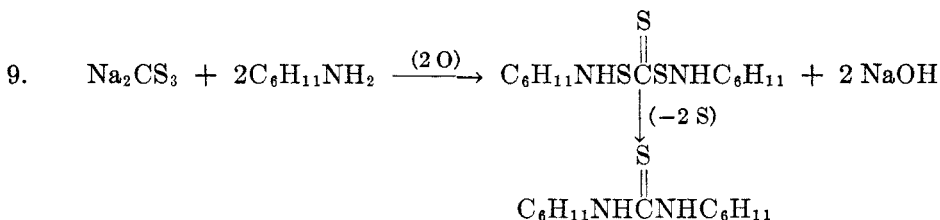
It was shown by Debus (5) and Mylius (6) that ammonia reacted with xanthogen disulfides to form xanthogen amide and ammonium xanthogenate. We have found that cyclohexylamine reacted with xanthogen disulfides to form the N-cyclohexylxanthogenamide and the corresponding xanthogenate.



Oxidative condensation of xanthates with amines did not yield sulfenamides nor did the reaction of xanthates with N-monochloroamines. This was indicated by the fact that none of the products were accelerators of rubber vulcanization. Thioamides were not isolated but were probably the main constituents of the complex reaction mixtures.

Oxidative condensation of cyclohexylamine and sodium trithiocarbonate produced dicyclohexylthiourea. This also corresponds to the formation of thioamides from carbidithioates and probably involves initial formation of a bis-

sulfenamide with immediate decomposition by loss of sulfur and the formation of the thiourea.



Disulfides were the products of a number of reactions designed to produce sulfenamides from carbodithioates and xanthates. The oxidation of cyclohexylammonium dithiofuroate yielded dithiofuroyl disulfide. N-Chlorourea and similar compounds did not react metathetically with sodium xanthates, but formed xanthogen disulfides.

EXPERIMENTAL

Preparation of dithio acids. Dithiobenzoic acid, α -dithionaphthoic acid, and dithio-*p*-toluic acid were prepared by reaction of the appropriate Grignard reagent and carbon disulfide as described by Houben and others (7). These acids were obtained in yields of 48%, 80%, and 30% respectively by this method.

α -Dithiofuroic acid was prepared by the action of sodium polysulfide on furfural according to the method of Leuck (8), which represents a modification of earlier work (9). Yields of 40–50% were obtained by us.

All of the dithio acids prepared were unstable, deep red or violet oils. They were purified by a series of extractions; that is, extraction of an ether solution of the acid with dilute aqueous alkali and extraction of the acidified aqueous solution of the sodium salt of the acid so formed with ether; this procedure was repeated until extraction of the ether solution by aqueous alkali left the ether layer colorless.

N-Cyclohexylthiobenzamide. To a solution of 13.2 g. (0.075 mole) of sodium dithiobenzoate in 250 ml. of water was added 37.5 g. (0.375 mole) of cyclohexylamine; to this a solution of 27 g. (0.1 mole) of iodine and 30 g. of potassium iodide in 200 ml. of water was added slowly and with stirring at a temperature of 5–10°. The red color of the solution disappeared and an oil formed. After allowing the reaction mixture to stand overnight, the oil was extracted with ether, the ether solution was washed several times with water and evaporated. The oily residue was triturated several times with water and gasoline added, after which the yellow crystalline solid was separated and dried. It melted at 82–85°. Recrystallized twice from gasoline, m.p. 91–92°.

Anal. Calc'd for $\text{C}_{13}\text{H}_{17}\text{NS}$: N, 6.40; S, 14.60.

Found: N, 6.44; S, 14.65.

This compound was also obtained from the reaction of sodium dithiobenzoate and N-monochlorocyclohexylamine, m.p. 90–92°; the mixture melting point (90–92°) with the above sample proved the two samples identical.

In order to establish definitely the structure of this compound, it was prepared by the reaction of phenylmagnesium bromide with cyclohexyl isothiocyanate.

To 0.08 mole of phenylmagnesium bromide in 200 ml. of ether was added 10.89 g. (0.077 mole) of cyclohexyl isothiocyanate in 50 ml. of ether. The reaction mixture was maintained below 5°, stirred, and the stirring continued at 5° for one hour after the addition was complete. The reaction mixture was allowed to come to room temperature, then poured on to ice, acidified, and the ether solution dried over sodium sulfate. Evaporation of the ether gave a solid residue, m.p. ca. 50°; yield, 15 g. (88%). Recrystallized once from gasoline,

m.p. 90–92°; mixture m.p. 90–92° (with material obtained from sodium dithiobenzoate as described above).

N-Cyclohexylthio-p-toluamide. This was prepared in a manner similar to that described above. After dissolving 0.3 mole of dithio-*p*-toluic acid, 2.9 g. of sodium hydroxide, and 15.7 g. (0.15 mole) of cyclohexylamine in water, the solution was diluted to 250 ml. and a solution of 8.09 g. (0.3 mole) of iodine dissolved in potassium iodide solution was added slowly and with stirring. The oily precipitate was isolated in ether, the ether solution dried, and evaporated. Yield, 6.7 g. of a pasty solid (95%) m.p. 80–90°. Repeated recrystallizations from ether-petroleum ether yielded a bright yellow crystalline compound, m.p. 104–105°.

Anal. Calc'd for $C_{14}H_{19}NS$: N, 6.00; S, 13.72.

Found: N, 5.96; S, 13.64.

N-Cyclohexylthio- α -naphthamide. To an aqueous solution of 100 g. (1.0 mole) of cyclohexylamine, 0.2 mole of sodium α -dithionaphthoate, and 4 g. of sodium hydroxide, was added at 5–10° with stirring, 0.2 moles of iodine (200 ml. of an iodine-potassium iodide solution 1.0 molar with respect to iodine). A bright yellow crystalline solid formed which turned to a red oil when the aqueous reaction medium was separated. The oil was triturated with several portions of water and finally with alcohol (95%); it solidified, m.p. 81–95°. Recrystallized repeatedly from ether, m.p. 97–98°.

Anal. Calc'd for $C_{17}H_{15}NS$: N, 5.19; S, 11.76.

Found: N, 5.19; S, 11.86.

To the Grignard reagent prepared from 23.4 g. (0.11 mole) of α -bromonaphthalene and 2.7 g. (0.11 mole) of magnesium in 200 ml. of ether was added slowly at 0–5°, 14.2 g. (0.1 mole) of cyclohexyl isothiocyanate dissolved in 50 ml. of ether. The temperature was maintained below 5° for two hours, with vigorous stirring. On allowing the mixture to stand over the weekend at room temperature a clear ether solution resulted. This was poured on to ice and the mixture was acidified. A solid which was insoluble in both water and ether separated, was removed, and the ether layer evaporated to an oil. This was dissolved in ether and from this solution on cooling to –10° separated a yellow crystalline solid which, after repeated recrystallizations, melted at 97–98°. Mixture melting point with the compound prepared from α -dithionaphthoic acid, was 96–98°, indicating identity.

N-Cyclohexylthiofuramide. A suspension of *N*-monochlorocyclohexylamine was prepared at –10° by adding 0.23 mole of sodium hypochlorite (86.8 ml., 2.65 *M*) to 0.25 mole of cyclohexylamine with stirring. To this suspension was added, also with stirring, a solution of 28.8 g. (0.2 mole) of dithiofuroic acid in 100 ml. of 10% sodium hydroxide solution. The solid precipitate was washed with water and dried; yield 43 g. (quantitative). After several recrystallizations from petroleum ether the material melted at 81–82°.

Anal. Calc'd for $C_{11}H_{15}NOS$: N, 6.70; S, 15.3.

Found: N, 6.88; S, 15.3.

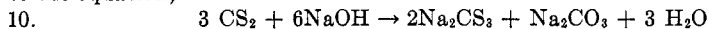
The oxidative condensation of cyclohexylamine with sodium thiobenzoate. Monothiobenzoic acid was prepared by the reaction of benzoyl chloride and freshly prepared potassium hydrosulfide. To 0.35 mole of sodium monothiobenzoate dissolved in 200 ml. of water was added 1.75 moles of cyclohexylamine and then 0.35 mole of iodine (350 ml., 1.0 *M* iodine-potassium iodide) was added slowly and with stirring at a temperature of 5–10°. The voluminous white precipitate was washed and dried; m.p. 146–147°. A mixture melting point with an authentic sample of *N-cyclohexylbenzamide* showed no depression.

Preparation of cyclohexylammonium dithiofuroate. To a solution of 25 g. (0.17 mole) of dithiofuroic acid in ether solution was added 16.8 g. (0.17 mole) of cyclohexylamine with stirring, the temperature being maintained at 0°. The cyclohexylammonium salt separated as deep red crystals. These were washed with ether and dried; yield 41 g. (quantitative), m.p. 110–112° with decomposition. After one recrystallization from water, m.p. 113–114° with decomposition.

Oxidation of cyclohexylammonium dithiofuroate with potassium ferricyanide. Cyclohexylammonium dithiofuroate (12.15 g., 0.05 mole) was suspended in 750 ml. of water and a solution of 32.9 g. (0.1 mole) of potassium ferricyanide in 200 ml. of water was added with stirring

at room temperature. The solution became colorless and a bright red precipitate formed. This was dried, m.p. 94–95°; yield 17 g., 92%. After one recrystallization from hexane, m.p. 100–101°. A mixture melting point with a known sample of dithiofuroyl disulfide showed no depression.

The oxidation of an aqueous solution of cyclohexylamine and sodium trithiocarbonate. A solution of sodium trithiocarbonate was prepared as described by Weeldenburg (10) from 22.8 g. of carbon disulfide, 33.6 g. of potassium hydroxide, and 200 ml. of water with the aid of a small amount of an emulsifying agent. Assuming that the reaction proceeds according to the equation,



the solution contained 0.2 mole of sodium trithiocarbonate. To half of this solution was added first, 24.4 g. of cyclohexylamine, and then a solution of 24.7 g. of iodine in 250 ml. of potassium iodide solution slowly and with stirring. Meanwhile the reaction mixture was cooled with ice-water. An oil separated which after standing overnight solidified to a mixture of red and cream-colored crystals. These were washed with water and dried. Yield, 12.4 g., m.p. 170–175°. After recrystallization from alcohol-water the m.p. was 175–177°. A mixture melting point with dicyclohexylthiourea prepared according to the method of Skita and Rolfe (11), m.p. 176–178°, showed no depression.

The reaction of cyclohexylamine with diethylxanthogen disulfide. Ten grams of diethylxanthogen disulfide was dissolved in 50 ml. of ether and into this was dropped slowly with stirring an ether solution containing 8.2 g. of cyclohexylamine. Reaction was almost immediate. A light yellow precipitate formed and there was some heat developed by the reaction. The rate of addition was maintained at such a slow rate that the temperature did not rise more than a few degrees. The precipitate was removed by filtration and was water-soluble (cyclohexylammonium ethylxanthate). The ether filtrate was evaporated leaving an oily mass of crystals; after recrystallization from petroleum ether three times, m.p. 49–50°.

Anal. Calc'd for $\text{C}_9\text{H}_{17}\text{NOS}$: N, 7.5. Found: N, 7.4.

The reaction of N-monochlorourea and potassium isopropylxanthate. A solution of 0.1 mole of N-monochlorourea was prepared by adding 63.9 ml. of a 1.57 molar solution of sodium hypochlorite to 6.05 g. (0.1 mole) of urea dissolved in 50 ml. of water at a temperature of 0–5°. To this solution was then added slowly and with stirring a solution of 17.4 g. (0.1 mole) of sodium isopropylxanthate dissolved in 50 ml. of water. The solid precipitate which formed was filtered off and dried, m.p. 55–57°. Diisopropylxanthogen disulfide has m.p. 58.5° (12).

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