Chemistry

B. V. KOPYLOVA, Corresponding Member of the Academy of Sciences of the USSR R. Kh. FREIDLINA

1964

SovietRxiv

Abstract

Full Text

Chemistry

B. V. KOPYLOVA, Corresponding Member of the Academy of Sciences of the USSR R. Kh. FREIDLINA

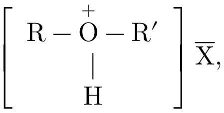
INTERACTION OF THIOUREA WITH ORGANIC SULFIDES, DISULFIDES, AND SULFENYL CHLORIDES IN AN ACIDIC MEDIUM

Recently we reported (^{1,2}) that, in the interaction of thiourea with simple ethers in an acidic medium, salts of S-alkylisothiouronium bases are formed according to the scheme:

$$\mathrm{ROR'} + \mathrm{SC(NH_2)_2} \xrightarrow{\mathrm{HX}} \mathrm{RSC(=NH)NH_2 \cdot HX} + [\mathrm{R'OH}]. \qquad (1)$$

This reaction has been carried out with examples of aliphatic, aliphatic-aromatic, and cyclic ethers, as well as ethers containing alkenyl groups and alkyls with substituents in the chain. Formic, trifluoroacetic, a mixture of formic and hydrochloric, or formic and hydrobromic acids were used as the acids.

We assumed that in this reaction oxonium salts of the type



$$\left[\begin{array}{c} \mathrm{R} - \overset{+}{\mathrm{O}} - \mathrm{R'} \\ | \\ \mathrm{H} \end{array}\right]\overline{\mathrm{X}},$$

are formed as intermediates, which can interact with thiourea, similarly to the reactions of simple ethers with other nucleophilic reagents in an acidic medium, by an S_N1 or S_N2 mechanism depending on the reaction conditions and the structure of the starting ether (^{3}).

Thioethers and other compounds of divalent sulfur differ from simple ethers in their lesser ability to form hydro-sulfonium compounds of the type $[\mathrm{R_2}\overset{+}{\mathrm{S}}\mathrm{H}]\overline{\mathrm{X}}$ (^{4}) with acids, and therefore one might have expected a different behavior of thioethers and other formally divalent sulfur compounds with thiourea in an acidic medium. It turned out that only thioethers containing a tert-butyl group —phenyl tert-butyl sulfide and n-butyl tert-butyl sulfide—behave analogously to ethers and, on heating with thiourea, for example in a trifluoroacetic acid medium, form a salt of S-tert-butylisothiouronium.

Di-*n*-butyl sulfide does not react with thiourea in a mixture of formic and hydrobromic acids under conditions in which di-*n*-butyl ether forms a salt of *S*-butylisothiouronium; this reaction also did not proceed in a trifluoroacetic acid medium.

Therefore we tested the action of thiourea on this thioether in concentrated sulfuric acid. In this case a salt of *S*-butylthioisothiouronium was obtained, isolated in the form of the picrate (n-$C_4H_9SSC(=NH)NH_2$ Pikr.). The same compound was obtained by the action of thiourea on dibutyl disulfide in sulfuric or formic acid medium, or on butylsulfenyl chloride in formic acid medium.

The preparation of one and the same compound starting from di-*n*-butyl sulfide, di-*n*-butyl disulfide, and from *n*-butylsulfenyl chloride according to scheme 2 is ...

as proof of the structure of *S*-*n*-butylthioisothiuronium, isolated in the form of the picrate.

$$\begin{matrix}(C_4H_9)_2S\\(C_4H_9S{-})_2\\C_4H_9SCl\end{matrix}\quad\longrightarrow\frac{SC(NH_2)_2}{HX}\longrightarrow C_4H_9SSC(=NH)NH_2HX. \tag{2}$$

This course of the reaction was also confirmed by the fact that, in the case of di-*n*-butyl disulfide, gas–liquid chromatography showed the simultaneous formation of butyl mercaptan.

Thus, we found that thioethers can react with thiourea in an acidic medium in two directions—with formation of salts of *S*-alkylisothiuroniums or salts of *S*-alkylthioisothiuroniums according to scheme 3:

$$RSR' + SC(NH_2)_2 \xrightarrow{HX} \begin{cases} RSC(=NH)NH_2HX, & a\\ RSSC(=NH)NH_2HX, & b\end{cases} \tag{3}$$

Whether the direction of the reaction depends on the nature of the acid was determined using the reaction of tert-butyl-*n*-butyl sulfide with thiourea as an example.

It proved that in sulfuric acid, in contrast to the reaction in trifluoroacetic acid, the reaction proceeds according to scheme 6 with formation of the salt of *S*-butylthioisothiuronium.

The interaction of isobutyl-*n*-butyl sulfide with thiourea in sulfuric acid likewise led to the preparation of the salt of *S*-*n*-butylthioisothiuronium. With phenylsulfenyl chloride as an example, the possibility of obtaining salts of *S*-arylthioisothiuronium bases was shown. Previously, *S*-alkyl-(aryl)-thioisothiuronium salts were not known. Of the three routes found for their preparation, the best yield is given by synthesis starting from sulfenyl chlorides. Compounds of this type can be obtained in good yield by chlorination of disulfides in formic acid medium and subsequent reaction with thiourea, without isolation of the sulfenyl chloride formed. Picrates of *S*-alkyl-(aryl)-thioisothiuroniums are readily purified by recrystallization; they have sufficiently high and sharp melting points and can serve for purposes of identification of disulfides and sulfenyl chlorides.

Experimental Part

Interaction of tert-butyl-*n*-butyl sulfide with thiourea in trifluoroacetic acid. A solution of 2.5 g of tert-butyl-*n*-butyl sulfide and 1.3 g of thiourea in 15 ml of trifluoroacetic acid was heated in a sealed ampoule on a boiling water bath for 20 h. The reaction mixture was evaporated in vacuo; the residue weighed 6.1 g. From 1 g of the substance, dissolved in alcohol, 0.7 g of *S*-tert-butylisothiuronium picrate was obtained, m.p. 154–155° (from alcohol). Yield 69% of theory; the melting point of a mixed sample with an authentic specimen showed no depression.

Interaction of tert-butyl phenyl sulfide with thiourea in trifluoroacetic acid. The experiment was carried out analogously to the preceding one, starting from 2.5 g of tert-butyl phenyl sulfide and 4.2 g of thiourea dissolved in 15 ml of trifluoroacetic acid. The yield of *S*-tert-butylisothiuronium picrate was 35% of theory, m.p. 154–155° (from alcohol); the melting point of a mixed sample with an authentic specimen showed no depression.

Interaction of di-*n*-butyl sulfide with thiourea in concentrated sulfuric acid. A solution of 2.5 g of di-*n*-butyl sulfide and 1 g of thiourea in 15 ml of conc. sulfuric acid was heated in a sealed ampoule on a boiling water bath for 20 h. From 3 g of the reaction mixture, diluted with alcohol, by addition of alcoholic solution of picric acid, followed by precipitation with water, there was obtained S-butylthioisothiuronium picrate, $(C_4H_9SSC(=NH)NH_2C_6H_2(NO_2)_3OH)$. After purification by boiling with activated charcoal in alcohol, 0.2 g of picrate was obtained, m.p. 162–163° (from alcohol), yield 29% of theory.

Found, %:	C 33.26; H 3.75; S 15.44, 15.62
$C_{11}H_{15}O_7N_5S_2$. Calculated, %:	C 33.58, H 3.84, S 16.30

Reaction of tert-butyl *n*-butyl sulfide with thiourea in concentrated sulfuric acid.

The experiment was carried out analogously to the preceding one, using 2.5 g of tert-butyl *n*-butyl sulfide, 1.3 g of thiourea, and 15 ml of sulfuric acid. The melting point of the S-butylthioisothiuronium picrate obtained was 157–158° (after a single purification by boiling with activated charcoal), yield 16% of theory. After a second recrystallization from alcohol, m.p. 162–163°; the melting point of a mixed sample with the specimen obtained in the preceding experiment showed no depression.

Reaction of isobutyl *n*-butyl sulfide with thiourea in concentrated sulfuric acid. The experiment was carried out analogously to the preceding one, using 2.5 g of isobutyl *n*-butyl sulfide and 1.3 g of thiourea dissolved in 10 ml of concentrated sulfuric acid. From 3 g of the reaction mixture, after three recrystallizations from alcohol with the addition of activated charcoal, 0.1 g of S-butylthioisothiuronium picrate was obtained, m.p. 162–163°; the melting point of a mixed sample with the picrate obtained in the preceding experiment showed no depression. Yield 9% of theory.

Reaction of di-*n*-butyl disulfide with thiourea in concentrated sulfuric acid. The experiment was carried out analogously to the preceding one, from 2.5 g of di-*n*-butyl disulfide and 1 g of thiourea in 15 ml of concentrated sulfuric acid. Heating time, 2 h. S-Butylthioisothiuronium picrate was obtained in a yield of 10% of theory, m.p. 162–163°. The melting point of a mixed sample with the picrate obtained from di-*n*-butyl sulfide showed no depression.

Reaction of di-*n*-butyl disulfide with thiourea in formic acid.

A mixture of 2.5 g of di-*n*-butyl disulfide and 1 g of thiourea in 15 ml of 85% formic acid was heated in a sealed ampoule on a boiling water bath for 10 h. The upper layer was separated (2 g) (by the GLC method it was found that this was unreacted di-*n*-butyl disulfide). The remaining reaction mixture was evaporated in vacuo; weight of the residue, 1.69 g. From the residue there was obtained 0.68 g of S-butylthioisothiuronium picrate, m.p. 162–163° (after one recrystallization from alcohol). The melting point of a mixed sample with the picrate obtained from dibutyl sulfide showed no depression. Yield 61% of theory (calculated on the reacted disulfide).

By the GLC method, butyl mercaptan was found in the reaction mixture (~50.5% of theory).

Reaction of *n*-butylsulfenyl chloride with thiourea in formic acid.

a) **From *n*-butylsulfenyl chloride.** A solution of 2.5 g of n-C_4H_9SCl and 1.5 g of thiourea in 15 ml of absolute formic acid was heated in a sealed ampoule on a boiling water bath for 10 h. After evaporation of the reaction mixture in vacuo, the residue weighed 4.14 g. From 1 g of the residue, dissolved in alcohol, 1.53 g of S-butylthioisothiuronium picrate was obtained, m.p. 162–163° (after one recrystallization from alcohol). The melting point of a mixed sample with the specimen obtained from $C_4H_9SC_4H_9$ showed no depression. Yield 82% of theory.

b) **From dibutyl disulfide.** A stream of chlorine was passed through a solution of 2.5 g of di-*n*-butyl disulfide in absolute formic acid until

increase in the weight of the reaction mixture by 0.9 g. Then 1.5 g of thiourea was added to the reaction mixture; the mixture was placed in a glass ampoule and heated on a boiling water bath for 10 h. The reaction mixture was evaporated in vacuo; the weight of the residue was 3.58 g. From 1 g of the substance, after purification with activated charcoal, 1.5 g of S-butylthioisothiuronium picrate was obtained, m.p. 157–158° (without recrystallization, yield 97% of theoretical).

Reaction of phenylsulfenyl chloride with thiourea in absolute formic acid. The experiment was carried out analogously to the preceding one, starting from 0.8 g of C_6H_5SCl and 0.4 g of thiourea in 15 ml of absolute formic acid. The yield of S-phenylthioisothiuronium picrate was 45.5% of theoretical, m.p. 152° (after one recrystallization from alcohol).

Found, %: C 38.61; 38.38; H 2.49; 2.37; N 16.70; 16.90
$C_{13}H_{11}O_7N_5S_2$. Calculated, %: C 37.76; H 2.66; N 16.96

Institute of Organoelement Compounds
Academy of Sciences of the USSR

Received
23 VI 1964

REFERENCES CITED

1. R. Kh. Freidlina, B. V. Kopylova, DAN, **153**, 626 (1963).
2. B. V. Kopylova, R. Kh. Freidlina, Izv. AN SSSR, ser. khim., **1964**, No. 9.
3. R. L. Burwell, Jr., Chem. Rev., **54**, 615 (1954).
4. D. S. Tarbell, D. P. Harnish, Chem. Rev., **49**, 1 (1951).

Note: Figure translations are in progress. See original paper for figures.

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.