FORMATION OF AMINOTETRAZINES AND TRIAZOLES BY ALKALINE HYDROLYSIS OF THIOSEMICARBAZIDE

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3,6-Diamino-1,2,4,5-tetrazine is formed by alkaline hydrolysis of thiosemicarbazide in the presence of oxidizing agents (oxygen, silver ions). 3,4,5-Triamino-1,2,4-triazole is formed when the temperature is raised and when oxidizing agents are absent.

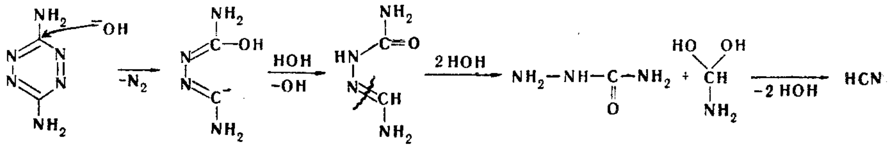
In a study of the alkaline hydrolysis of thiosemicarbazide (I) we directed our attention to the fact that aqueous alkaline solutions of I, isolated from contact with air oxygen, can be stored without change for as long as one pleases. In the presence of oxygen these solutions rapidly turn red, and the red color becomes increasingly more intense on storage; moreover, the concentration of I determined by amperometric titration [1] decreases with time (pH 14.1):

Time (days)	0	1	2	5	10	14
[I] mole/liter	0.100	0.099	0.097	0.086	0.076	0.064

Considering the well-known fact of the hydrolytic decomposition of I to hydrogen sulfide and cyanohydrazine [see the scheme below, step (1)] [2], we assumed that the cyanohydrazine is subsequently dimerized to 3,6-diamino-1,2-dihydro-1,2,4,5-tetrazine [II, step (2)], which in turn is very readily oxidized to red 3,6-diamino-1,2,4,5-tetrazine [III, step (3)] [3]. The fact of the synthesis of tetrazine III by oxidation of an alkaline solution of S-methylthiosemicarbazide [4] indicates the fundamental possibility of this sort of reaction.

In order to verify this assumption we synthesized III by the method in [4], recorded its electronic spectrum in the visible region, and compared it with the spectrum of a solution of I that had stood in air. With respect to the form of the curves and the position of the absorption maxima, both spectra coincide completely, and this indicates the correctness of our assumption.

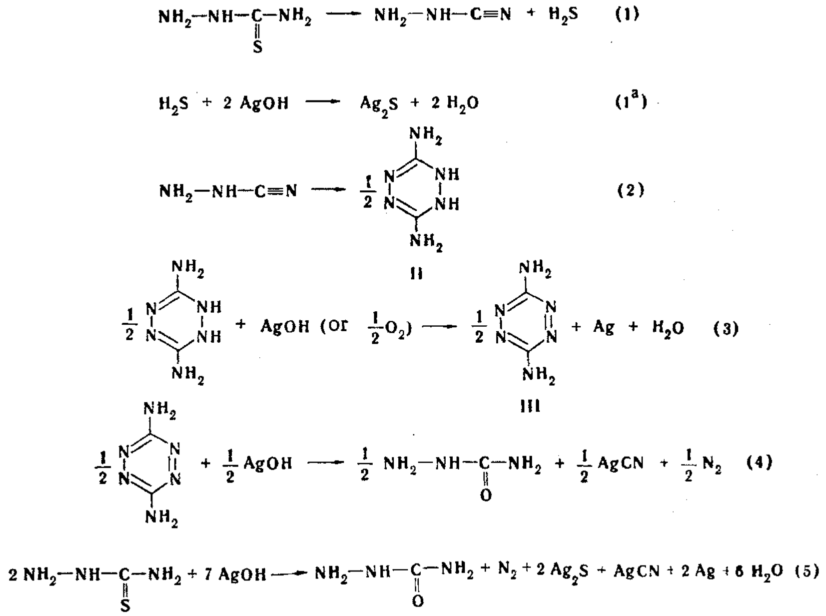
In a study of the alkaline hydrolysis of I in the presence of Ag^+ ions we observed that silver sulfide, silver cyanide, and silver metal are formed in the reaction and molecular nitrogen is evolved. The concepts regarding the mechanism of the hydrolysis of I set forth above enabled us to assume that the silver sulfide is formed by the reaction of hydrogen sulfide with Ag^+ ions [step (I^a)], that silver metal is formed by oxidation of II by silver ions [step (3)], and silver cyanide and nitrogen are formed by nucleophilic attack of the electron-deficient ring of III (which is extremely characteristic for tetrazines [5]), probably via the following mechanism:



S. M. Kirov Ural Polytechnic Institute, Sverdlovsk. Translated from Khimiya Geterotsiklicheskikh Soedinenii, No. 6, pp. 847-849, June, 1975. Original article submitted April 24, 1974.

The possibility of this sort of decomposition of III was verified by carrying out the reaction between authentic tetrazine III and an alkaline solution of silver nitrate. The experiment showed that molecular nitrogen is actually liberated in the reaction and that silver cyanide is formed.

The combination of all of the proposed reactions makes it possible to write overall Eq. (5). We experimentally verified the authenticity of the stoichiometric coefficients of Eqs. (4) and (5) by means of chemical analysis of the precipitates. We did not prove the formation of semicarbazides via Eq. (4), inasmuch as this was previously done in [6]. An analysis of the reacting products (see the experimental section) shows that the proposed and experimentally found stoichiometries coincide.

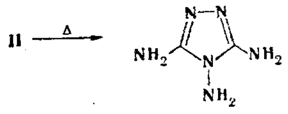


$$NH_2{-}NH{-}\underset{\overset{\|}{S}}{C}{-}NH_2 \longrightarrow NH_2{-}NH{-}C{\equiv}N + H_2S \quad (1)$$

$$H_2S + 2\,AgOH \longrightarrow Ag_2S + 2\,H_2O \quad (1^a)$$

$$2\,NH_2{-}NH{-}\underset{\overset{\|}{S}}{C}{-}NH_2 + 7\,AgOH \longrightarrow NH_2{-}NH{-}\underset{\overset{\|}{O}}{C}{-}NH_2 + N_2 + 2\,Ag_2S + AgCN + 2\,Ag + 6\,H_2O \quad (5)$$

It is known from the literature data [7] that dihydrotetrazines are similarly unstable and are readily converted on heating to the more stable 1,2,4-triazole derivative. In this connection, we assumed that if the equilibria of the first two steps are shifted to favor the formation of dihydrotetrazine II (for example, by hydrogen sulfide evolution) and II is heated without allowing the possibility of oxidation to tetrazine III, one should realize the isomerization of II to 3,4,5-triamino-1,2,4-triazole (guanazine) (IV).



IV

Our expectations were confirmed by heating an aqueous solution of I with the oxide (PbO) of a difficult-to-reduce metal [to prevent step (3)]. Guanazine was obtained in good yield, and the accessibility of the starting materials and the simplicity involved in the isolation of the guanazine make it possible to recommend the described method as a preparative method.

EXPERIMENTAL METHOD

Hydrolysis of Thiosemicarbazide (I). Sodium hydroxide was added to a solution of 0.3645 g (4 mmole) of I in distilled water to pH 12, after which 2.718 g (16 mmole) of silver nitrate was added, and the solution was stirred for 20 min. During this period, nitrogen gas was evolved and a black precipitate formed. At the end of the reaction, the solution was acidified to pH 5 with nitric acid (1:4) in order to extract the silver hydroxide from the precipitate. The presence of silver sulfide and silver metal in the dried precipitate was proved by x-ray diffraction analysis, and the C≡N absorption band of silver sulfide was proved by IR spectroscopy. An analysis of the precipitate by the method in [8] showed that it contained 1.009 g (4.05 mmole) of silver sulfide, 0.415 g (3.85 mmole) of silver metal, and 0.258 g (1.94 mmole) of silver cyanide, i.e., the stoichiometric coefficients of Eq. (5) were obtained within the limits of the experimental error.

Hydrolysis of 3,6-Diamino-1,2,4,5-tetrazine (III). The pH of a solution of 1.12 g (10 mmole) of tetrazine III in water was brought up to 12 with sodium hydroxide, and 8.5 g of silver nitrate was added to the solution. Nitrogen was evolved in the form of bubbles, and silver cyanide precipitated. The weight of the dry precipitate was 1.34 g [as compared with 1.34 g calculated from Eq. (4)].

3,4,5-Triamino-1,2,4-triazole (IV). A solution of 45.5 g (0.5 mole) of I in 1 liter of freshly distilled water was heated on a water bath to 90-95°, and 233 g (1 mole) of lead oxide was added in small portions with stirring. The completion of the reaction was monitored by the absence of darkening when a sample of the solution was heated with lead oxide. At the end of the reaction, the hot solution was filtered and evaporated to dryness. The solid residue was crystallized from 20 ml of water with the addition of activated charcoal and aluminum oxide to give 21 g (74%) of a product with mp 257°. Found: C 21.3; H 5.6; N 73.4%. Calculated: C 21.0; H 5.3; N 73.7%. No melting-point depression was observed for a mixture of this product with a sample obtained in [9], and the product formed the previously described [10] triacetyl derivative.

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