INVESTIGATION OF 2,1,3-THIA- AND 2,1,3-SELENADIAZOLES

LXVIII.* HALOGENATION AND SULFONATION OF NAPHTHO[1,2-d] [2,1,3]THIADIAZOLE

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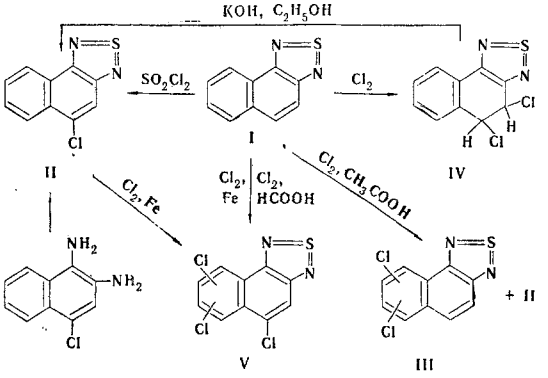
The position of entry of the substituent in the electrophilic substitution of naphtho[1,2-d]-[2,1,3]thiadiazole depends on the nature of the attacking reagent: depending on the experimental conditions, 5-chloro and di- and trichloro-substituted derivatives and 4-bromo and dibromo derivatives are formed during chlorination and bromination. In the absence of a catalyst, naphthothiadiazole is chlorinated by sulfuryl chloride to give 5-chloronaphthodiazole; 5-bromonaphthothiadiazole is formed with N-bromosuccinimide in the presence of anhydrous aluminum chloride. The 6-, 7-, 8-, and 9-amino derivatives of naphthothiadiazole are converted to the corresponding chloro and bromo derivatives by the Sandmeyer reaction. Depending on the experimental conditions, 4-sulfo (or chlorosulfo) and disulfo (or dichlorosulfo) derivatives are formed in the sulfonation and chlorosulfonation of naphthothiadiazole. As in the naphthalene series, the sulfo (or chlorosulfo) group can be replaced by chlorine (or bromine). Phthalic acid is obtained in the oxidation of 4-bromonaphthothiadiazole with potassium permanganate.

It has been demonstrated [2] that, depending on the experimental conditions, the 5-chloro derivative (II) and a dichloro derivative (III) of undetermined structure (mp 138-140°C) are formed in the chlorination of naphtho[1,2-d][2,1,3]thiadiazole (I) in acetic acid. The action of chlorine on fused I in the absence of iron gives the product of the addition of two chlorine atoms – 4,5-dichloro-4,5-dihydronaphtho[1,2-d][2,1,3]-thiadiazole (IV) – which is converted to II by treatment with alcoholic alkali.



In the present paper we report the results of a further study of the halogenation and the sulfonation of I. The chlorination of I with sulfuryl chloride under the usual conditions gives II. Trichloro derivative V, in which one chlorine atom apparently occupies the 5 position, is primarily formed by the action of chlorine on fused I or II in the presence of iron or by chlorination of I in formic acid. When I is chlorinated in acetic acid, a considerable amount of III is isolated along with II.

*See [1] for communication LXVII.

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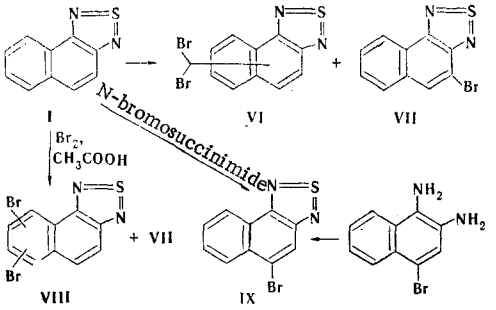

Dibromo derivative VI with mp 210-212° is primarily formed by the action of bromine on fused I in the presence or absence of iron. The 4-bromo derivative (VII) is isolated as a side product. The latter is the chief product in the bromination of I in acetic acid. Under these conditions, the side product is dibromonaphthothiadiazole VIII (mp 132°) of unestablished structure. The structure of VII was proved by oxidation with potassium permanganate to give phthalic acid and also by comparison of it with five other isomeric 5-, 6-, 7-, 8-, and 9-bromonaphthothiadiazoles (IX-XIII, respectively). Bromo derivative IX was obtained by the reaction of 4-bromo-1,2-naphthalenediamine [2] with thionylaniline and also by bromination of I with N-bromosuccinimide in the presence of anhydrous aluminum chloride. Bromo derivatives X-XIII were obtained by the Sandmeyer reaction from the corresponding amines (XIV-XVII) [1].

Heating I with 17-18% oleum at 140-150° for 1 h gives primarily a disulfo derivative, which is converted to the corresponding dichloro derivative (XVIII) with mp 178° on chlorination. The latter is also obtained when I is heated with chlorosulfonic acid at 140-150° for 4 h with subsequent heating with thionyl chloride and chlorination of the reaction product. In this case, the reaction proceeds through the intermediate formation of the corresponding disulfonyl dichloride (XIX) with mp 190-192°, which was isolated and converted under similar conditions to the above-mentioned dichloro derivative (XVIII). A dibromo derivative (XX) of undetermined structure was obtained by the action of 6% aqueous bromine on disulfonyl dichloride XIX.

The sulfonation of I with 18% oleum at 110-120° for 1 h or with 60% oleum at 20° for 5 h gives the 4-sulfo derivative (XXI), which is converted to the 4-chloro derivative (XXII) on chlorination. The latter is also obtained by heating of I with chlorosulfonic acid for 4 h on a boiling-water bath with subsequent heating with thionyl chloride and chlorination of the reaction product. It should be noted that the conversion of sulfo derivatives I to the chloro (or bromo) derivatives is apparently accompanied by destruction, as a result of which the yield of halo derivatives is low (several percent). Destruction is also observed in the conversion of 4-sulfobenzo-2,1,3-selenadiazole to the 4-chloro derivative [3].

The structure of chloro derivative XXII was established by comparison of it with the five other isomers – 5-, 6-, 7-, 8-, and 9-chloronaphthothiadiazoles (II and XXIII-XXVI, respectively). Chloro derivatives XXIII-XXVI (see Table 1) were obtained by the Sandmeyer reaction from the corresponding amino derivatives (XIV-XVII) [1].

The entry of chlorine into the 5 position and of bromine and the sulfo group into the 4 position shows that the maximum electron density under the conditions of these reactions is situated on the 5 and 4 carbon atoms, respectively. Thus, depending on the nature of the attacking reagent, different distributions of the electron density are observed in the electrophilic substitution reactions of I (in [1] it was established that in the nitration of I the nitro group enters the 6 and 9 positions). Naphtho[1,2-d][2,1,3]oxadiazole behaves similarly under electrophilic substitution conditions (the nitro group enters the 6 and 8 positions, while the chloro and sulfo groups enter the 4 position) [4,5]. The reason for this apparently consists in the unsymmetrical orientation of the heteroring relative to the benzene rings. It is known [6-8] that in the electrophilic substitution of benzothia(selena)diazole the substituent enters the same position [4 (7)] in all cases (nitration, sulfonation, halogenation, chloromethylation, etc.). The different directions of substitution in naphthothia(oxa)diazole as a function of the nature of the electrophilic reagent are consequently due to disruption of the symmetry characteristic for benzothiadiazole. In fact, the benzothiadiazole molecule is uniformly polarized, and the shift of electrons to the electron-withdrawing thiadiazole ring in the course of the reaction occurs uniformly, regardless of the nature of the electrophilic reagent. In the case of naphthothiadiazole, which can be considered to be a benzothiadiazole substituted in the 4 and 5 (6 and 7) positions by a divinylene group, which has highly polarizable π bonds, the redistribution of electron density during the reaction should be irregular and readily variable as a function of the character of the electro-

TABLE 1. Halo Derivatives of Naphtho[1,2-d][2,1,3]thiadiazole

Comp.	Substituent	mp, °C *	Empirical formula	Found, %			UV spectrum	
				N	S	halogen	λ_{max}, nm	lg ε
XXII	4-Cl	104		12,2	14,5	15,7	270, 276, 350, 368	4,61, 4,69, 4,00, 4,03
II	5-Cl	124		—	—	16,5	268, 276, 330, 354	4,88, 4,55, 3,78, 3,86
XXIII	6-Cl	98—100	$C_{10}H_5ClN_2S$†	12,7	15,1	15,7	270, 276, 346	4,68, 4,74, 4,17
XXIV	7-Cl	154—159		—	—	16,0	274, 278, 326, 340	4,04, 4,04, 3,45, 3,63
XXV	8-Cl	127—129		—	14,9	—	278, 324, 344, 360	4,45, 3,57, 3,65, 3,67
XXVI	9-Cl	136—137		13,0	—	15,7	268, 272, 296, 315, 346	4,02, 4,02, 3,12, 3,00, 3,60
VII	4-Br	128—129		—	—	30,6	270, 276, 332, 350	4,44, 4,61, 3,84, 3,90
IX	5-Br	124—125		10,6	—	30,5	272, 278, 346, 362	4,28, 4,34, 3,99, 4,00
X	6-Br	105—107	$C_{10}H_5BrN_2S$‡	10,0	—	30,6	276, 350, 366	3,50, 3,84, 3,83
XI	7-Br	147—150		10,9	12,6	30,4	268, 274, 290, 344	4,46, 4,50, 3,88, 4,08
XII	8-Br	158—159		10,0	11,9	30,2	274, 280, 345, 360	4,31, 4,43, 3,74, 3,75
XIII	9-Br	152—153		—	—	30,3	260, 268, 348, 365	4,37, 4,42, 3,85, 3,37

*Compound XXIII was recrystallized from 60% alcohol, XXVI was recrystallized from glacial acetic acid, IX was recrystallized from 50% acetic acid, and the remaining compounds were recrystallized from alcohol.

†Calculated: Cl 16.1; N 12.7; S 14.5%.

‡Calculated: Br 30.2; N 10.6; S 12.1%.

philic reagent. The electron densities of the individual positions of the molecule will, of course, be different for different electrophilic reactions.

Electronic Spectra

The electronic spectra are presented in Figs. 1 and 2 and in Table 1. Only a slight bathochromic shift occurs when substituents such as chloro and bromo groups are introduced into I. A hypsochromic shift is observed in the 9 position. In this case, the shift of the π electrons is apparently accompanied by weakening of the conjugation. A similar pattern is observed in the spectra of the dichloro and dibromo derivatives. The introduction of two chlorine or bromine atoms causes a slight bathochromic shift.

The addition of two chlorine atoms leads to a slight bathochromic shift and converts the structured absorption band to a smooth curve with one broad maximum. This can be explained by the fact that, in contrast to the chloro-substituted compounds, the aromatic benzene and thiadiazole rings in 4,5-dihydrodichloronaphthodiazole do not form a single aromatic system and are separated to a considerable extent by the C–C single bond.

IR Spectra

The spectra of 4-chloro- and 5-chloronaphthothiadiazoles differ completely from the spectra of the analogous bromo derivatives. If, however, these substituents are in the 6, 7, 8, and 9 positions, the spectra of the chloro and bromo derivatives are almost identical in identical positions. Two regions – 1200-1700 and 700-1000 cm^{-1} – can be isolated in the spectra of the chloro and bromo derivatives. The absorption bands in the first region are shifted by about 30 cm^{-1} to the high-frequency side on passing from the chloro to the bromo derivatives. As in the case of aromatic systems, these absorption bands are due to the va-

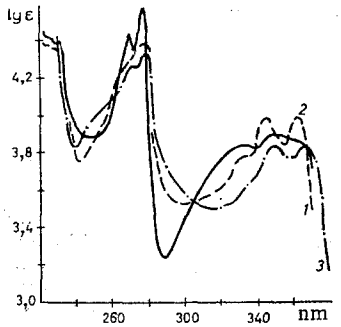

Fig. 1. UV spectra (in ethanol): 1) 5-bromonaphtho[1,2-d][2,1,3]thiadiazole (IX); 2) 6-bromonaphtho[1,2-d][2,1,3]thiadiazole (X); 3) 4-bromonaphtho[1,2-d][2,1,3]thiadiazole (VII).

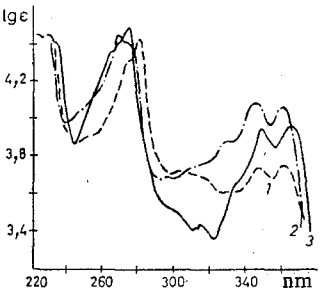

Fig. 2. UV spectra (in ethanol): 1) 8-bromonaphtho[1,2-d][2,1,3]thiadiazole (XII); 2) 7-bromonaphtho[1,2-d][2,1,3]thiadiazole (XI); 3) 9-bromonaphtho[1,2-d][2,1,3]thiadiazole (XIII).

lence vibrations of the ring C–C bonds. The position of the C–H bands at 700-1000 cm^{-1}, i.e., in the region of the out-of-plane deformation vibrations, remains virtually unchanged on passing from the chloro to bromo derivatives. The frequencies of the absorption bands change only when the positions of the substituents change and are in good agreement with the frequencies of the corresponding substituted aromatic systems [9]. Thus the absorption bands caused by substituents attached to naphthothiadiazoles are found in the same regions as those of other aromatic compounds.

EXPERIMENTAL

5-Chloronaphtho[1,2-d][2,1,3]thiadiazole (II). A. Chlorine was passed at 100° for 1 h through a solution of 2 g (0.01 mole) of I [2] in 90 ml of glacial acetic acid, after which the mixture was cooled and diluted with water. The oily mass was extracted with ether. The ether was removed from the extract, and the residue was crystallized successively from acetic acid (with charcoal) and alcohol to give 1.15 g (49%) of colorless needles of II (see Table 1). The mother liquor yielded a colorless substance with mp 138-140° (from alcohol), which was identified as x,x'-dichloronaphtho[1,2-d][2,1,3]thiadiazole (III). Found, %: N 11.1, 10.7; S 12.3, 12.5. $C_{10}H_4Cl_2N_2S$. Calculated, %: N 11.0; S 12.2.

B. A mixture of 2 g of I and 13 ml of sulfuryl chloride was refluxed for 1 h, and the excess sulfuryl chloride was removed by distillation. The residue was crystallized from alcohol to give 1.4 g (59%) of II.

C. The same compound was obtained from 4-chloro-1,2-diaminonaphthalene and thionyl aniline via the method in [2].

D. The same compound was obtained from IV by heating with alcoholic alkali [2].

The samples obtained via methods A-D did not depress one another's melting points.

6-Chloronaphtho[1,2-d][2,1,3]thiadiazole (XXIII). A mixture of 1.3 g (6.5 mmole) of amine XIV and 33 ml of hydrochloric acid (sp. gr. 1.19) was refluxed for 30 min. It was then cooled to 0°, and 0.5 g (7.2 mmole) of sodium nitrite in 1 ml of water was added. This mixture was then held at 0° for 30 min and at 20° for 1 h, after which it was filtered. A solution of 1.3 g of freshly prepared cuprous chloride in 10 ml of hydrochloric acid (sp. gr. 1.19) was added with stirring at 0° to the filtrate, and the mixture was stirred at 0° for 15 min and at 20° for 30 min. It was then heated on a boiling-water bath for 1 h and cooled. The precipitate was removed by filtration and washed with hydrochloric acid (sp. gr. 1.19) and water until it was neutral. The product was reprecipitated from alcohol solution by the addition of water and crystallized from aqueous alcohol to give 0.4 g (28%) of XXIII. Chloro derivatives XXIV-XXVI (Table 1) were similarly obtained.

5-Bromonaphtho[1,2-d][2,1,3]thiadiazole (IX) [2]. A mixture of 1 g of I, 1.5 g of N-bromosuccinimide, 2.5 g of anhydrous aluminum chloride, and 20 ml of dry carbon tetrachloride was heated for 2 h, and the resulting dark-brown mass was poured into 150 ml of water. The aqueous layer was separated from the carbon tetrachloride, and the solvent was evaporated to dryness. The residue was crystallized from alcohol (with charcoal) to give a colorless substance with mp 122-124° that did not depress the melting point of bromo derivative IX, obtained via the method in [2]. The reaction products were identified by chromatography in a loose layer of activity II (Brockmann classification) aluminum oxide with detection in UV light and with iodine vapors.

4-Bromonaphtho[1,2-d][2,1,3]thiadiazole (VII). A solution of 25 ml of bromine in 45 ml of glacial acetic acid was added dropwise to 37.2 g (0.2 mole) of crude I (mp 70°) in 240 ml of glacial acetic acid, and the mass was refluxed for 30 min and allowed to stand overnight. The precipitate was removed by filtration and washed with acetic acid to give 38.5 g (72%) of bromo derivative VII with mp 127-129°; the product depressed the melting point of 5-bromonaphthothiadiazole (IX) and did not correspond to any of the five isomeric bromo derivatives (see Table 1). The mother liquor yielded x,x'-dibromo derivative VIII with mp 132-132.5° (from alcohol). Found, %: N 8.2, 8.3; Br 46.9, 46.4. $C_{10}H_4Br_2N_2S$. Calculated, %: N 8.2; Br 46.5.

6-Bromonaphtho[1,2-d][2,1,3]thiadiazole (X). A 1-g (5 mmole) sample of amine XIV in 25 ml of hydrobromic acid (sp. gr. 1.382) was diazotized at 0° with a solution of 0.35 g (5 mmole) of sodium nitrite in 0.5 ml of water. The filtered solution was poured into 1 g of cuprous bromide in 9 ml of hydrobromic acid (sp. gr. 1.382), and the mass was heated on a boiling-water bath for 1.5 h. It was then cooled, and the precipitate was removed by filtration, washed with water, and crystallized from alcohol to give colorless needles of X. Bromo derivatives XI-XIII (Table 1) were similarly obtained.

4-Chloronaphtho[1,2-d][2,1,3]thiadiazole (XXII). A. A total of 4.5 ml of chlorosulfonic acid was added with cooling to 2 g of I at such a rate that the mixture remained at room temperature. The mixture was then heated on a boiling-water bath for 4 h. It was then cooled, and 3.5 ml of thionyl chloride was added. This mixture was heated on a boiling-water bath for 1 h, cooled, and poured into 200 g of crushed ice. The precipitate was removed by filtration, washed with water until it was neutral, and transferred to a distilling flask containing 5 ml of hydrochloric acid (sp. gr. 1.19). Live steam was then passed into the flask while a solution of 2 g of potassium chlorate in 30 ml of water was added dropwise. The chloro derivative in the distillate was crystallized from alcohol (see Table 1).

B. A total of 25 ml of 60% oleum was added dropwise at 20° in the course of 1.5 h to a mixture of 5 g of I and 35 ml of concentrated sulfuric acid, and the mass was held at this temperature for 4 h. It was then poured over 200 g of ice, and the mixture was filtered. The filtrate was treated with barium carbonate. The precipitated barium sulfate was separated and washed with water, and the filtrate was evaporated to dryness. Water (25 ml) and 5.6 ml of hydrochloric acid (sp. gr. 1.19) were added to the residue, and a solution of 1.45 g of $KClO_3$ in 20 ml of water was added dropwise in the course of 3 h with simultaneous removal of the reaction product by steam distillation to give colorless crystals that did not depress the melting point of a sample of XXII from experiment A.

4-Sulfonaphtho[1,2-d][2,1,3]thiadiazole (XXI). A mixture of 5 g of I and 50 ml of 18% oleum was heated at 110-120° for 1 h, after which it was cooled and poured over 200 g of ice. The mixture was filtered, and the filtrate was treated with barium carbonate. The precipitated barium sulfate was removed by filtration and washed with water, and the filtrate was passed through a column containing KU-1 cation exchange resin. The acid thus obtained was evaporated, and an accurately weighed sample of the acid was dissolved in a 50-ml volumetric flask. A fifth of the resulting solution was titrated potentiometrically with a glass electrode–calomel electrode circuit. Found: E 260.7. $C_{10}H_6N_2O_3S_2$. Calculated: E 266.

Oxidation of 4-Bromonaphtho[1,2-d][2,1,3]thiadiazole (VII). A mixture of 6.88 g of bromo derivative VII, 1.6 g of potassium hydroxide, and 100 ml of water was heated to the boiling point, and a solution of 18.7 g of potassium permanganate in 120 ml of water was added in portions, after which the mixture was refluxed for another 30 min. Alcohol (10 ml) was added to decompose the excess potassium permanganate. The mixture was cooled, and the manganese dioxide was removed by filtration. The filtrate was acidified (with respect to Congo) with hydrochloric acid and evaporated to dryness. The residue was extracted with ether. The ether was evaporated, and the residue was crystallized from water to give a substance with mp 178-179° that was identical to phthalic acid.

The UV spectra of alcohol solutions of the compounds were recorded with an SF-4A spectrophotometer. The IR spectra of mineral oil suspensions were recorded with a UR-10 spectrometer.

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