REACTION OF 2-ACETYLBENZOTHIAZOLE WITH 2-FORMYLBENZOTHIAZOLE

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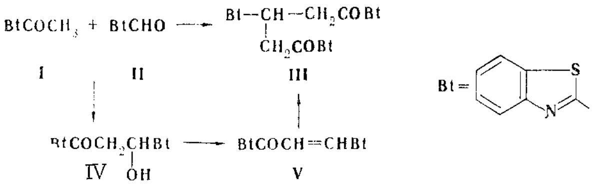
Products of condensation of 2-acetylbenzothiazole with 2-formylbenzothiazole and other aldehydes of the heterocyclic series were obtained, and their structures and properties were investigated. It is shown that some of them react with acids or alkalis to give dyes.

The realization of the synthesis of the simplest thiacyanine dye that does not contain alkyl groups attached to the nitrogen atoms of the benzothiazole rings (northiacarbocyanine) [1] compelled us to attempt to investigate the possibility of the preparation of other norcyanines with aromatic character and to search for methods for their synthesis.

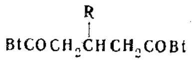
In the present research we investigated the reaction of 2-acetylbenzothiazole (I) with 2-formylbenzothiazole (II). The reaction of these substances leads to products with various structures, depending on the reaction conditions. A substance, which, in analogy with [2-4], is either 1,5-diketone III or α,β-unsaturated ketone V, is formed when a mixture of the starting substances with anhydrous ethanol is allowed to stand for many hours in the presence of piperidine.



The results of complete elementary analysis and the mass-spectral determination of the molecular mass are in good agreement with the values calculated for diketone III (Table 1). The IR spectrum of the substance provides evidence for the presence of a CO group and for the absence of an OH group. The presence of a carbonyl group in the substance is also indicated by the reaction with phenylhydrazine, and elementary analysis of the phenylhydrazone indicates the presence of two carbonyl groups (Table 2). The formation of 1,4,6-tri(2-benzothiazolyl)pyridine (VI) when the diketone is fused with ammonium acetate constitutes evidence that these groups are in the 1 and 5 positions relative to one another.

Finally, the diketone structure (III) of the investigated compound was proved by synthesis: The condensation of ketone I with aldehyde II in a mixture of ethanol with pyridine and in the presence of triethylamine gives hydroxy ketone IV, which was converted by heating with acetic anhydride to a chalcone analog (V) of the benzothiazole series, which in ethanol in the presence of piperidine adds a molecule of ketone I to give a product that is identical to diketone III.

We synthesized analogs of diketone III, viz., diketones VIIa-c (Table 1), by the same method; however, for the preparation of VIId ketone I was condensed with benzaldehyde in the presence of sodium ethoxide, since α,β-unsaturated ketone VIII — an analog of chalcone — is formed when the condensation is carried out in ethanol with piperidine. Ketone VIII adds ketone I in the presence of sodium ethoxide to give diketone VIId.


$$\mathrm{BtCOCH_2\overset{R}{\overset{|}{C}}HCH_2COBt}$$

VII a-d

$\mathrm{BtCOCH_2CH_2Bt}$

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TABLE 1. 1,5-Diketones III and VII

Compound	R	Reaction time, days	mp, °C (solvent)	IR spectrum, cm^{-1}	Empirical formula	Found/calc., %				Yield, %
						C	H	N	S	
III[a]	2-Benzothiazolyl	6	204	1640	$C_{26}H_{17}N_3O_2S_3$	62,1 62,5	3,6 3,4	8,4 8,4	19,1 19,2	22
VIIa[b]	2-Pyridyl	3	178 (acetonitrile)		$C_{24}H_{17}N_3O_2S_2$	64,9 65,0	3,6 3,8	9,5 9,5	14,1 14,4	66
VIIb	2-Quinolyl	3	185	1680	$C_{28}H_{19}N_3O_2S_2$	68,0 68,1	3,8 3,9	8,2 8,5	12,7 13,0	38,5
VIIc	*p*-NO_2—C_6H_4	20	225 (dioxane)	1680 1510 1340	$C_{25}H_{17}N_3O_4S_2$	61,9 61,6	3,5 3,5	8,5 8,6	13,1 13,2	61,7
VIId	C_6H_5	3	215—217 (nitromethane)		$C_{25}H_{18}N_2O_2S_2$			6,3 6,3	14,6 14,5	56,5 (A) 43 (B)

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[a] Mass spectrum: $[M]^+$ 499, 367, 365, 333, 322, 231, 203, 177, 176, 167, 162, 161, 135 (100%), 134, 125. [b] PMR spectrum (in $CDCl_3$): 3.53-4.53 (m, 5H) and 7.03-8.53 ppm (m, 12H).

TABLE 2. Bis(phenylhydrazones) of Diketones III and VII

Diketones	Bis(phenylhydrazones)						
	mp, °C	found, %		empirical formula	calculated, %		yield, %
		N	S		N	S	
III	144	13,9	14,2	$C_{38}H_{29}N_7S_3$[a]	14,4	14,2	85
VIIa	165	15,7	10,3	$C_{36}H_{29}N_7S_2$	15,7	10,3	96
VIIb	151	14,4	9,6	$C_{40}H_{31}N_7S_2$	14,6	9,5	89
VIIc	140	14,6	9,5	$C_{37}H_{29}N_7O_2S$[b]	14,7	9,6	90
VIId	105	13,8	10,0	$C_{37}H_{30}N_6S_2$	13,5	10,3	70

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[a] Found: C 66.9; H 4.6%. Calculated: C 67.1; H 4.3%. [b] Found: C 66.6; H 4.9%. Calculated: C 66.5; H 4.4%.

Diketones III and VIIa, b gradually become red when an alcohol solution of alkali or alkoxide is added; the dyes that are formed in solution are characterized by light-absorption curves with two maxima near 540 and 570 nm. Dyes with light-absorption curves that are typical for cyanine dyes are formed when diketones III and VIIa, b are heated with a solution of hydrogen chloride in isopropyl alcohol (only the dye formed in the reaction of ketone III with hydrogen chloride in isopropyl alcohol was isolated; the remaining dyes were investigated in solutions in ethanol or methylene chloride). Dyes are not formed from ketones VIIc, d.

Considering the results of a study of the simplest northiacarbocyanine, which was obtained from 1-hydroxy-1,3-di(2-benzothiazolyl)propane [1], we assume that the dyes formed from the diketones by the action of alkalis on them are N-metal-substituted derivatives of the norcyanine bases, while the dyes formed by treatment of the diketones with hydrogen chloride are norcyanines. The establishment of the structures of these dyes will be the subject of future research.

The data that we have accumulated make it possible to predict that other 1,3-dihetarylpropanes, the molecules of which are constructed from two identical or different residues of nitrogen heterocycles with aromatic character connected to the propane skeleton by means of their α positions with a hydrocarbon chain containing one double bond or substituents that ensure the possibility of the formation of a double bond, will, upon reaction with alkalis or acids, also undergo conversion to colored N-metal-substituted derivatives of norcyanine bases or, correspondingly, norcyanines. In fact, a dye characterized by a broad light-absorption band with two maxima at 514 and 568 nm is formed when an alcohol solution of alkali or alkoxide is added to an alcohol solution of ketone IX, while a dye with a light-absorption curve that is typical for cyanines with λ_{max} 575 nm (probably a norcarbocyanine) is formed when a solution of hydrogen chloride in isopropyl alcohol is added.

EXPERIMENTAL

The IR spectra of KBr pellets of the compounds were recorded with a UR-20 spectrometer. The PMR spectra were recorded with a Tesla BS-467 spectrometer (60 MHz) with hexamethyldisiloxane as the internal standard. The positions of the chief light-absorption maxima were determined in solutions in ethanol or methylene chloride with an SF-10 spectrophotometer. The mass spectra were recorded by direct introduction of samples into the ion source with a Varian Mat 311A spectrometer under standard operating conditions.*

1,5-Di(2-benzothiazolyl)-1,5-pentanediones (III, VIIa-c). A 0.4-0.5-ml sample of piperidine was added to a warm solution of 0.01 mole of ketone I and 0.005 mole of the aldehyde in 10-30 ml of anhydrous ethanol, and the mixture was allowed to stand at 20°C for 1-6 days; in the first 1-2 days the solution, which contained a precipitate, was heated to the boiling point two to three times. The reaction product was removed by filtration, washed with warm alcohol or acetone and ether, and crystallized from dioxane, acetonitrile, or chloroform (charcoal was used where necessary). Data on the individual diketones are presented in Table 1.

3-Phenyl-1-(2-benzothiazolyl)-2-propen-1-one (VIII). This compound was obtained in 78% yield from ketone I and benzaldehyde by a method similar to that used in the preceding experiment; the reaction time was 3 days. The product was crystallized from 75% aqueous dioxane using charcoal. The fine yellowish crystals had mp 150°C. IR spectrum: 1650 (CO) and 985 cm^{-1} (trans CH=CH). Found: C 72.4; H 4.9; N 5.3; S 12.1%. $C_{16}H_{11}NOS$. Calculated: C 72.5; H 4.2; N 5.3; S 12.1%.

1,3,5-Tri(2-benzothiazolyl)-1,5-pentanedione (III). A 0.1-ml sample of piperidine was added to a warm solution of 0.14 g (4 mmole) of unsaturated ketone V and 0.07 g (4 mmole) of ketone I in 20 ml of anhydrous ethanol, and the mixture was heated to the boiling point and allowed to stand for 20 h. The precipitate was removed by filtration and washed with ethanol to give 0.06 g of a product with mp 203°C (from nitromethane). No melting-point depression was observed for a mixture of this product with a previously obtained sample of diketone III.

1,3-Di(2-benzothiazolyl)propan-2-on-3-ol (IV). A mixture of 2.6 g (15 mmole) of ketone I, 2.4 g (15 mmole) of aldehyde II, 60 ml of anhydrous ethanol, 6 ml of pyridine, and 0.2 ml of triethylamine was heated until the components dissolved, and the solution was allowed to stand at 20°C for 7 days. It was then filtered, and the very small amount of precipitate was discarded. Water (100 ml) was added to the filtrate, and the mixture was allowed to stand for 1 h. The precipitate was removed by filtration and washed with water and 10 ml of ethanol to give 2.1 g (41%) of fine colorless crystals with mp 168°C (from nitromethane). IR spectrum: 1680 (CO) and 3200 cm^{-1} (OH). Found: C 59.9; H 3.4; N 8.1%. $C_{17}H_{12}N_2O_2S_2$. Calculated: C 60.0; H 3.6; N 8.2%.

1,3-Di(2-benzothiazolyl)-3-propen-1-one (V). A mixture of 1.0 g (3 mmole) of hydroxy ketone IV with 10 ml of acetic anhydride was refluxed for 40 min, after which it was allowed to stand for 15-20 h. The precipitate was removed by filtration and washed with alcohol to give 0.6 g (64%) of fine shiny crystals with mp 197°C (from nitromethane). IR spectrum: 1700 (CO) and 1620 cm^{-1} (—C=C—). Found: C 62.8; H 3.3; N 8.7%. $C_{17}H_{10}N_2OS_2$. Calculated: C 63.3; H 3.1; N 8.7%.

1,3-Di(2-benzothiazolyl)-3-phenyl-1,5-pentanedione (VIId). A) A 0.18-g (1 mmole) sample of ketone I and 0.27 g (1 mmole) of ketone VIII were dissolved in 30 ml of anhydrous ethanol, 0.07 g (1 mmole) of dry sodium ethoxide was added, and the mixture was heated to the boiling point and allowed to stand for 20 h. The precipitate was washed with 20 ml of hot ethanol to give 0.25 g (56.5%) of a product with mp 215-217°C (from nitromethane). Found: N 6.3; S 14.6%. $C_{25}H_{18}N_2O_2S_2$. Calculated: N 6.3; S 14.5%.

B) A 0.1-g (1 mmole) sample of benzaldehyde and 0.068 g (1 mmole) of dry sodium ethoxide were added to a warm solution of 0.18 g (2 mmole) of ketone I in 10 ml of anhydrous ethanol, and the mixture was allowed to stand for 3 days. The precipitate was removed by filtration and washed with hot ethanol to give 0.19 g (43%) of a product with mp 215-216°C (from nitromethane). A mixture of the substances obtained by methods A and B melted in a capillary at 215-216°C.

Bis(phenylhydrazones) of Diketones III and VIIa-d. A mixture of 0.5-1 mmole of the diketone, 2-4 mmole of phenylhydrazine, and 1-4 ml of glacial acetic acid was refluxed for

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*The authors than I. S. Shpileva for the mass spectrometric measurements.

1-4 h, after which the bishydrazone was precipitated by the addition of water. The bishydrazone of diketone VIIa was isolated by neutralization of the acetic acid solution with 40% aqueous sodium carbonate solution and was crystallized from 75% aqueous acetic acid, nitromethane, petroleum ether, or heptane. Data on the individual bishydrazones are presented in Table 2.

2,4,6-Tri(2-benzothiazolyl)pyridine (VI). A mixture of 0.5 g (1 mmole) of diketone III with 3 g of ammonium acetate was heated at 190°C for 3 h, after which 20 ml of water and a 20% aqueous solution of sodium carbonate were added until the mixture gave an alkaline reaction. The precipitate was washed with water to give 0.2 g (41.8%) of fine yellowish needles that melted in a capillary above 350°C (from DMSO). The IR spectrum did not contain a CO band. Found: C 64.5; H 2.8; N 11.4; S 19.9%. $C_{26}H_{14}N_4S_3$. Calculated: C 65.2; H 2.9; N 11.7; S 20.1%.

Reaction of Diketones III and VIIa, b with Hydrogen Chloride. A mixture of 0.5-0.7 mmole of the diketone with 10 ml of a 20% solution of HCl in isopropyl alcohol was heated with stirring at 80°C for 10 min, after which the precipitated dye was removed by filtration and washed with isopropyl alcohol and petroleum ether. The dye from diketone III was obtained in 33.3% yield after washing; the fine dark crystals with a metallic luster had mp 260°C and λ_{max} 598 nm (in methylene chloride). The product was analyzed without further purification. Found: Cl 11.5; N 7.5; S 16.9%. $C_{26}H_{19}Cl_2N_3O_2S_3$. Calculated: Cl 12.4; N 7.3; S 16.8%.

The dyes from diketones VIIa and VIIb were unstable. Immediately after washing, they were dissolved in methylene chloride, and the freshly prepared solutions were used for spectroscopy. The absorption curve of the dye formed from diketone VIIa is characterized by a broad absorption band and λ_{max} 618 nm, while the curve of the dye obtained from diketone VIIb is characterized by two maxima at 625 and 668 nm.

1,3-Di(2-benzothiazolyl)propan-1-one (IX). A warm solution of 0.45 g (4.5 mmole) of chromic anhydride in 3 ml of 80% acetic acid was added with stirring in the course of 1-2 min to a heated (to 95°C) solution of 1.63 g (5 mmole) of 1,3-di(2-benzothiazolyl)propan-1-ol [1] in 8 ml of 80% acetic acid, and the mixture was heated at 103-105°C for 30 min and mixed with 30 ml of water. The emulsion was extracted four times with ether (200 ml), and the extract was dried with sodium sulfate, shaken with 1.2 g of charcoal for 5 min, and filtered. The ether was removed by distillation, and the acetic acid residues were removed *in vacuo* with a water aspirator. The residual mass was triturated with 15 ml of 10% aqueous hydrochloric acid until it solidified. The solid material was removed by filtration, washed with 10% hydrochloric acid and water, and crystallized from 7 ml of ethanol using charcoal to give 0.2 g (12.5%) of fine acicular crystals with mp 121°C. IR spectrum: 1700 cm^{-1} (CO); the spectrum did not contain an OH band. PMR spectrum ($CDCl_3$): complex multiplet of protons of methylene groups centered at 3.7 ppm [A_2B_2 system (4H)] and a multiplet of aromatic protons at 7.23-8.23 ppm (8H). Found: C 62.6; H 3.8; N 8.6%. $C_{17}H_{12}N_2OS_2$. Calculated: C 63.0; H 3.7; N 8.6%.

A dye with a broad light-absorption band with a high degree of absorption in the shortwave region and two poorly expressed maxima at 514 and 568 nm was formed when sodium ethoxide was added to an alcohol solution of ketone IX; the dye formed from the ketone by the addition of a solution of HCl in isopropyl alcohol to it is characterized by a curve that is typical for cyanine dyes with λ_{max} 575 nm.

The phenylhydrazone of ketone IX was obtained as yellow crystals with mp 145°C (from ethanol). Found: N 13.4; S 15.4%. $C_{23}H_{31}N_4S_2$. Calculated: N 13.5; S 15.5%.

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