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Reaction of Aldehydes with Hydrazine in the System Sulfur–Alkali*

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Abstract—Dissolution of sulfur in the system hydrazine hydrate–alkali leads to strong activation of hydrazine, so that the latter readily reacts at room temperature with aldehydes of the aromatic and thiophene series to give the corresponding aldehyde azines in high yield. The mechanism of activating effect of sulfur is discussed.

Aromatic aldehyde azines are obtained by reactions of aldehydes with hydrazinium salts or hydrazones derived from various carbonyl compounds, which are carried out in alcohol, dry benzene, or polyphosphoric acid at 100°C [1–4]. Aldehyde azines of the thiophene series were prepared only from 2-thiophenecarbaldehyde and 5-trimethylsilyl-2-thiophenecarbaldehyde by heating them with hydrazine hydrate in anhydrous alcohol under reflux. However, the yield of the corresponding azines did not exceed 60% [5].

In continuation of our studies on reactions of sulfur solutions with electrophilic reagents in basic reducing systems, we examined such reactions with aldehydes of the aromatic and thiophene series. Formaldehyde and paraformaldehyde are known to react with the above sulfur solutions to give poly(methylene polysulfides) [6]. We found that no sulfurization of substituted benzaldehydes or thiophenecarbaldehyde

derivatives occurs in the system sulfur–hydrazine hydrate–sodium hydroxide. Instead, hydrazine effectively reacts with aldehydes **Ia**–**Ih** at room temperature, affording the corresponding aldehyde azines **IIa**–**IIh**. The reaction is complete almost instantly, and the yield of products **II** reaches 86% (Scheme 1). The reaction conditions and product yields are given in Table 1. Aldehyde azines **II** on the basis of thiophenecarbaldehyde derivatives were synthesized for the first time (Table 2). They were characterized by IR and ^{1}H NMR spectra. The ^{1}H NMR spectral parameters of **IIa**–**IIh** are given in Table 3.

The activating effect of sulfur in this reaction may be explained as follows. Sulfur reacts with alkali to give sulfide anions which are solvated by hydrazine with formation of a complex with charge separation. Thus a solution of sulfur in the system hydrazine hydrate–alkali is a complex reagent like **III** which reacts with aldehyde. The hydrazine molecule strongly activates sulfide ions, e.g., as shown in Scheme 2. The reaction of complex **III** with aldehyde could involve

Scheme 1.

RCHO + H$_2$NNH$_2$ + NaOH + S
Ia–Ih

$\longrightarrow$ RCH=N—N=CHR
IIa–IIh
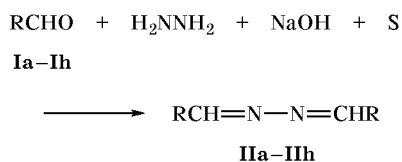
R = Ph (**a**), 2-ClC$_6$H$_4$ (**b**), 4-ClC$_6$H$_4$ (**c**), 2-thienyl (**d**), 5-chloro-2-thienyl (**e**), 5-(2-thienyl)-2-thienyl (**f**), thieno-[2,3-*b*]thiophen-2-yl (**g**), 5-(2-thienylthio)-2-thienyl (**h**).

Scheme 2.
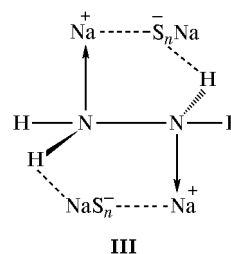
III

Table 1. Reactions of aldehydes **Ia–Ih** with hydrazine in the system sulfur–sodium hydroxide

Aldehyde no.	Amounts of reactants, g (mol)					Yield of **II**	
	S	NaOH	N_2H_4–H_2O	H_2O (ml)	RCHO (I)	g	%
Ia	3.84 (0.12)	4.0 (0.1)	5.0 (0.1)	30	10.6 (0.1)	8.4	86
Ia	3.2 (0.1)	3.05 (0.05)[a]	25.0 (0.5)	–	21.1 (0.2)	11.7	56
Ia	0.96 (0.03)	2.0 (0.05)[a]	12.0 (0.4)	–	12.7 (0.12)	9.2	74
Ib	1.28 (0.04)	1.3 (0.033)	1.66 (0.033)	10	4.66 (0.033)	1.5	33
Ic	3.84 (0.12)	4.0 (0.1)	5.0 (0.1)	30	14.0 (0.1)	11.6	84
Id	0.5 (0.0156)	0.6 (0.0156)	3.0 (0.06)	5	1.76 (0.0156)	1.3	76
Ie	0.45 (0.014)	0.56 (0.014)	1.0 (0.02)	3	2.0 (0.014)	1.7	86
If	0.3 (0.009)	0.3 (0.0075)	1.0 (0.02)	3	1.6 (0.008)	1.3	82
Ig	0.32 (0.01)	0.4 (0.01)	1.0 (0.02)	3	1.68 (0.01)	1.4	84
Ih	0.64 (0.02)	0.6 (0.015)	0.8 (0.015)	5	0.004 (0.98)	0.5	52

[a] 2-Aminoethanol was used instead of alkali solution.

Table 2. Melting points and elemental analyses of aldehyde azines **IIa–IIh**

Comp. no.	mp, °C	Found, %					Formula	Calculated, %				
		C	H	S	N	Cl		C	H	S	N	Cl
IIa	85	81.75	5.82	–	12.43	–	$C_{14}H_{12}N_2$	80.77	5.77	–	13.46	–
IIb	70–72	59.85	3.78	–	10.69	25.74	$C_{14}H_{10}N_2Cl_2$	60.60	3.60	–	10.00	25.60
IIc	205–207	59.62	3.99	–	10.14	25.90	$C_{14}H_{10}N_2Cl_2$	60.60	3.60	–	10.00	25.60
IId	151–152	54.66	3.51	29.26	13.36	–	$C_{10}H_8N_2S_2$	54.55	3.64	29.09	12.73	–
IIe	148–149	41.53	1.69	22.50	9.75	24.00	$C_{10}H_6Cl_2N_2S_2$	41.52	2.06	22.16	9.69	24.57
IIf	191–192	56.65	3.38	33.01	6.96	–	$C_{18}H_{12}N_2S_4$	56.25	3.12	33.33	7.29	–
IIg	195	49.22	2.32	37.89	8.40	–	$C_{14}H_8N_2S_4$	50.60	2.41	38.55	8.43	–
IIh	125	47.64	2.41	41.56	6.45	–	$C_{18}H_{12}N_2S_6$	48.21	2.68	42.86	6.25	–

intermediate generation of the corresponding thioaldehyde which reacts with hydrazine at a higher rate than does initial aldehyde [7]. Probably, activated sulfide ions favor cleavage of the carbonyl bond to give carbocation which is subjected to attack by hydrazine. Complex formation between hydrazine and sulfide ions was also presumed by us in the reactions of thiols and disulfides with dihaloalkanes in the system hydrazine hydrate–alkali [8]. Moreover, all reactions of alkyl halides with sulfur solutions in the system hydrazine hydrate–alkali occur under mild conditions and require no heating; by contrast, they are accompanied by heat evolution (unlike sulfur reactions with alkyl halides in aqueous–alcoholic solutions of alkalies) [9, 10]. These data also support our assumption that activation of sulfur or its derivatives in basic reductive systems (hydrazine hydrate–alkali among these) involves generation of complexes.

Depending on the electrophile nature, complexes like **III** can act as either thionating or aminating agent.

Apart from aqueous alkali, we also used 2-aminoethanol to dissolve sulfur [11]. In this case, the molar ratio sulfur–2-aminoethanol–hydrazine hydrate was 1:0.5:5 or 1:1.5:15. The latter ensured a greater yield of benzaldehyde azine (**IIa**) from benzaldehyde (**Ia**). However, the reaction occurred only on heating at 75°C for 2–3 h. Probably, the activation of hydrazine in complex **III** is weaker in the absence of alkali metal cation.

Thus dissolution of sulfur in the system hydrazine hydrate–alkali considerably activates hydrazine via complex formation with sulfide ions. The developed procedure ensures effective reactions of hydrazine with various aldehydes to obtain practically important aldehyde azines. The products are monomers and starting compounds for preparation of various hetero-

Table 3. ^{1}H NMR spectra of aldehyde azines **IIa**, **IIb**, and **IId**–**IIh**

Comp. no.	Chemical shifts δ, ppm	
	CH=N	H$_{arom}$^{a}
IIa	2.71 s	7.88 m (*m*-H), 7.52–7.50 m (*p*-H, *o*-H)
IIb	9.02 s	8.21–8.19 m (*o*-H), 7.43–7.24 m (*p*-H, *m*-H)
IId	8.84 s	7.78 d (5-H), 7.62 t (4-H), 7.20 d (3-H)
IIe	8.55 s	7.15 d (4-H), 6.92 d (3-H)
IIf	8.6 d	7.28 m
IIg	8.76	7.54 m
IIh	8.53	7.24 m

^{a} Protons in the benzene and thiophene rings.

cycles, polymers and copolymers, metal complexes, medicines, etc. The synthesis of new aldehyde azines of the thiophene series attracts specific interest, for their chemistry has not been studied.

EXPERIMENTAL

The ^{1}H NMR spectra were recorded on a Bruker DPX-400 spectrometer (400 MHz) in CDCl$_3$ using HMDS as internal reference. The IR spectra were measured on a Sample Scant 250 IFS-25 instrument from samples pelleted with KBr.

General procedure for preparation of aldehyde azines. An aqueous solution of sodium hydroxide, sulfur, and hydrazine hydrate (molar ratio 1:1:1) was prepared in a three-necked flask equipped with a stirrer, reflux condenser, thermometer, and adapter for loading reactants. The solution was heated for 2 h at 80–85°C (to obtain the complex) and was then cooled to room temperature. Aldehyde **Ia**–**Ih** was added at room temperature. The reaction was accompanied by heat evolution, and aldehyde azine **II** instantaneously separated from the solution. The product was filtered off, washed with water, dried, and analyzed. Substituted benzaldehyde azines were isolated as yellow powders. Aldehyde azines of the thiophene series were orange to dark red powders. The reaction conditions and yields of products **IIa**–**IIh** are given in Table 1. Tables 2 and 3 contain their melting points, analytical data, and ^{1}H NMR parameters.

The IR spectra of **II** contain an absorption band at 1600 cm^{-1} due to stretching vibrations of the C=N bond. The physical constants of previously known compounds **IIa**–**IIc** were reported in [4], and of compound **IId**, in [5].

Reaction of benzaldehyde with hydrazine in the system sulfur–2-aminoethanol. Sulfur was dissolved in the system hydrazine hydrate–2-aminoethanol (molar ratio 0.03:0.4:0.05), the solution was heated for 2–3 h at 80–85°C and cooled to room temperature, and benzaldehyde (**Ia**) was added. The reaction was accompanied by heat evolution, but the product did not separate from the solution. The mixture was heated for 2 h at 75°C, and benzaldehyde azine (**IIa**) precipitated (Table 1).

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