Reactions of 5,6-dihydro-4,7-dithia-1,3-indandione with aldehydes and ketones

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5,6-Dihydro-4,7-dithia-1,3-indandione reacted with aromatic aldehydes in the molar ratio 1 1 yielding 2-arylmethylene-5,6-dihydro-4,7-dithia-1,3-indandione and with acetaldehyde in the ratio 2 : 1 giving 2,2′-ethylidenedi(5,6-dihydro-4,7-dithia-1,3-indandione); with acetone, butanone, cyclopentanone, and cyclohexanone it reacted in a similar way as with the aromatic aldehydes.

Было определено, что 5,6-дигидро-4,7-дитиа-1,3-индандион реагирует с ароматическими альдегидами в молярном отношении 1:1, причем возникает 2-арилметилен-5,6-дигидро-4,7-дитиа-1,3-индандион, но с ацетальдегидом реагирует в отношении 2:1, причем получается 2,2′-этилиденди(5,6-дигидро-4,7-дитиа-1-3-индандион). Реакции вышеуказанного соединения с ацетоном, бутаноном, циклопентаноном и циклогексаноном протекают аналогично как с ароматическими альдегидами.

Different properties of 1,3-indandione and 5,6-dihydro-4,7-dithia-1,3-indandione (further dithiaindandione), namely the different stability of keto and enol forms [1], gave us an impulse to investigate the reaction of dithiaindandione with some aldehydes and ketones under the same conditions as used in the reaction with 1,3-indandione. It is known that 1,3-indandione reacted with some aromatic aldehydes in the ratio 1 1 yielding 2-arylmethylene-1,3-indandione or in the ratio 2 : 1 yielding 2-arylmethylenedi(1,3-indandione) according to the reaction conditions [2—4]. With formaldehyde or acetaldehyde it reacted in the ratio of 2 : 1 affording in addition to the compounds mentioned also more complicated products [2, 5, 6]. Thus 1,3-indandione undergoes autoaldol condensation and the formed bindone reacts with aldehyde [7, 8].

From the reactions of 1,3-indandione with ketones, the greatest attention was paid to the reaction with acetone [9—11] because the resulting product had a complicated structure which was a subject of many discussions. The latest work [12] seemed to have solved this problem definitively. To the reactions of 1,3-indandione with other ketones no attention was paid till recently when reactions with cyclopentanone and cyclohexanone were accomplished [13]. It was found that 1,3-indandione reacted in the ratio 1 1.

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Experimental

Infrared spectra were measured using a UR-20 (Zeiss, Jena) spectrophotometer in chloroform (except when otherwise stated). Electronic spectra were taken on a Perkin—Elmer 450 spectrophotometer in the region of 215—715 nm; concentration 10^{-3}—10^{-4} M in dry methanol.

The p.m.r. spectra were measured on a Tesla BS-487A spectrophotometer in $CDCl_3$ at the working frequency 80 MHz using tetramethylsilane as a standard. The molecular weight of the compound *XXVII* was determined by an MCH 1303 mass spectrometer.

Melting points (Kofler) and the other characteristics are presented in Table 1 (*I—XVI*) and Table 2 (*XVII—XXIV*).

2-(X-Benzylidene)-5,6-dihydro-4,7-dithia-1,3-indandione (I—X, XIII—XVI) and 2-(5-X-furfurylidene)-5,6-dihydro-4,7-dithia-1,3-indandione (XVII—XXIV)

Method A

Into a flask provided with a reflux, dithiaindandione (3.72 g; 0.02 mole), the appropriate aldehyde (0.02 mole), and 96% ethanol (50—80 ml) were added. After dissolving the components, piperidine (2 drops) was added and the reaction mixture was refluxed for 15 min. Acetic acid (2 drops) was added into the cooled solution and the precipitated crude product was crystallized from ethanol or acetic acid.

Method B

Dithiaindandione (3.72 g; 0.02 mole), the appropriate aldehyde (0.02 mole), and sulfuric acid (3 drops) were heated on a water bath for 1 hr. After cooling, the corresponding benzylidenedithiaindandione precipitated during 24 hrs.

2-(4-Hydroxybenzylidene)-5,6-dihydro-4,7-dithia-1,3-indandione (XI)

The compound *x* (0.01 mole), acetic acid (15 ml), and 38% hydrobromic acid (40 ml) were heated for 3 hrs under reflux. After cooling, hot water (250 ml) was added and the crude product was crystallized from acetic acid.

2-(4-Aminobenzylidene)-5,6-dihydro-4,7-dithia-1,3-indandione (XII)

Into a three-necked flask fitted with a stirrer and a reflux, tin chloride dihydrate (1.5 g), acetic acid (10 ml), and hydrochloric acid (2 ml) were added. When tin dichloride was dissolved, *XVI* (0.002 mole) was added and the reaction mixture was stirred at 80°C for 2 hrs. After cooling, the salt of the corresponding amine precipitated and was transferred into free amine by washing with ammonia. The crude product was crystallized from acetone.

2,2'-Ethylidenedi(5,6-dihydro-4,7-dithia-1,3-indandione) (XXV)

Dithiaindandione (1.88 g; 0.01 mole) and acetaldehyde (1.08 g; 0.02 mole) in pyridine (5 ml) were allowed to react at room temperature for 24 hrs under occasional stirring. Pyridine was distilled off *in vacuo* and the crude product was crystallized from acetic acid. Yield 1.2 g (30%); m.p. 228—230°C.

For $C_{16}H_{14}O_4S_2$ (398.54) calculated: 48.22% C, 3.54% H, 32.18% S; found: 47.34% C, 3.61% H, 32.30% S. The i.r. spectra (hexachlorobutadiene) $\nu_s(C{=}O)$ 1717, $\nu_{as}(C{=}O)$ 1695, $\nu(C{=}C)$ 1520; p.m.r. (CF_3CO_2H) δ(p.p.m.) (CH_3) 0.77, (CH—) 2.51, (S—CH_2) 2.98, (CH—CO) 3.03.

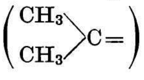
2-(2-Hydroxyethylidene)-5,6-dihydro-4,7-dithia-1,3-indandione (XXVI)

The mixture of dithiaindandione (3.76 g; 0.02 mole), glycolaldehyde (1.20 g; 0.02 mole), and piperidine (2 drops) in 96% ethanol (50 ml) was boiled. After cooling, acetic acid (2 drops) was added and the precipitated crude product was crystallized from ethanol. Yield 2.16 g (95%); m.p. 160–162°C.

For $C_9H_8O_3S_2$ (228.29) calculated: 47.41% C, 3.54% H, 28.13% S; found: 47.20% C, 3.30% H, 28.40% S. The i.r. spectra (nujol) $\nu_s(C{=}O)$ 1730, $\nu_{as}(C{=}O)$ 1700, $\nu(C{=}C)$ 1610, $\nu(SC{=}CS)$ 1540, $\nu(OH)$ 3400.

2-Isopropylidene-5,6-dihydro-4,7-dithia-1,3-indandione (XXVII)

To acetone (14 ml; 0.192 mole), dithiaindandione (1.86 g; 0.01 mole) and piperidine (0.7 g) in alcohol were added and the reaction mixture was heated for 2 hrs. (When potassium hydroxide was used instead of piperidine, the reaction proceeded at laboratory temperature already.) After cooling the crude product precipitated and was crystallized from acetic acid. Yield 2.03 g (90%); m.p. 253–254°C.

For $C_{10}H_{10}O_2S_2$ (226.32) calculated: 53.02% C, 4.45% H, 28.33% S; found: 53.48% C, 4.45% H, 28.27 S. The i.r. spectra ($CHCl_3$) $\nu_s(C{=}O)$ 1722, $\nu_{as}(C{=}O)$ 1675, $\nu(C{=}C)$ 1639, $\nu(SC{=}CS)$ 1525. Electronic spectrum (methanol) $\lambda(\varepsilon)$ 366 (15 700), 293 (10 900); p.m.r. ($CDCl_3$) δ (p.p.m.)  $\left(\begin{matrix}CH_3\\CH_3\end{matrix}\!\!>\!C{=}\right)$ 2.37, ($SCH_2{-}SCH_2$) 3.21.

2-Isobutylidene-5,6-dihydro-4,7-dithia-1,3-indandione (XXVIII)

Dithiaindandione (1.86 g; 0.01 mole), methyl ethyl ketone (0.72 g; 0.01 mole), and a concentrated solution of potassium hydroxide in alcohol (3 drops) were refluxed for 6 hrs. The product formed was crystallized from 60% acetic acid. Yield 1.7 g (80%); m.p. 188–190°C.

For $C_{11}H_{12}O_2S_2$ (240.00) calculated: 55.05% C, 5.04% H, 26.72% S; found: 55.14% C, 5.15% H, 26.71% S. The i.r. spectra (nujol) $\nu_s(C{=}O)$ 1711, $\nu_{as}(C{=}O)$ 1666, $\nu(C{=}C)$ 1624, $\nu(SC{=}CS)$ 1535.

2-Cyclohexylidene-5,6-dihydro-4,7-dithia-1,3-indandione (XXIX) and 2-cyclopentylidene-5,6-dihydro-4,7-dithia-1,3-indandione (XXX)

Dithiaindandione (3.72 g; 0.02 mole), the corresponding ketone (0.02 mole), and piperidine in alcohol (2 drops) were heated for 20 min on a water bath. After cooling, the precipitated yellow crystalls were recrystallized from ethanol.

XXIX: Yield 4.3 g (82%); m.p. 224–226°C.

For $C_{13}H_{14}O_2S_2$ (266.38) calculated: 58.60% C, 5.31% H, 24.11% S; found: 58.40% C, 5.02% H, 24.04% S. The i.r. spectra (nujol) $\nu_s(C{=}O)$ 1704, $\nu_{as}(C{=}O)$ 1667, $\nu(C{=}C)$ 1610, $\nu(SC{=}CS)$ 1537.

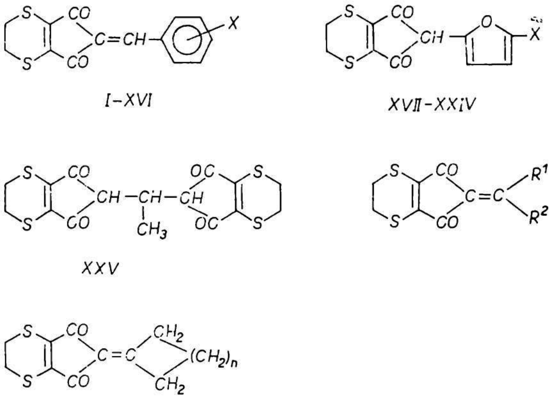
XXX: Yield 4.2 g (85%); m.p. 285–286°C.

For $C_{12}H_{12}O_2S_2$ (252.35) calculated: 57.20% C, 4.80% H, 25.45% S; found: 57.40% C, 5.10% H, 25.60% S. The i.r. spectra (nujol) $\nu_s(C{=}O)$ 1712, $\nu_{as}(C{=}O)$ 1644, $\nu(C{=}C)$ 1610, $\nu(SC{=}CS)$ 1524.

Results and discussion

The reactions of dithiaindandione with aromatic aldehydes were carried out at similar conditions as the reactions of 1,3-indandione [5].

It was found that under the mentioned conditions, dithiaindandione reacted with the aromatic aldehydes in the ratio 1 1 yielding 2-arylmethylene-5,6-dihydro-4,7-dithia-1,3-indandione. Dithiaindandione reacted in this ratio with both the substituted benzaldehydes (*I—XV*) and the 5-substituted 2-furaldehydes. It is to be noted that the compounds containing hydroxyl group were prepared by Zeissel method from the corresponding methoxy derivatives by treatment with hydrobromic acid. The compounds containing an amino group were prepared from the appropriate nitro derivatives by reduction with tin dichloride.



XXX $n = 2$
XXIX $n = 3$
XXVI $R^1 = H, R^2 = CH_2CH_2OH$
XXVII $R^1 = R^2 = CH_3$
XXVIII $R^1 = CH_3, R^2 = C_2H_5$

Scheme 1

The attempts to prepare compounds with a structure resulting from the reaction of two molecules of dithiaindandione and one molecule of aldehyde were unsuccessful even if a treefold excess of dithiaindandione was used. Neither the addition of dithiaindandione to the obtained arylmethylene-5,6-dihydro-4,7-dithia-1,3-indandione resulted in the corresponding bi derivative, though addition of 1,3-indandione to 2-(*p*-nitrobenzal)-1,3-indandione has been carried out [5].

The reaction of dithiaindandione with above-mentioned benzaldehydes was carried out also in acetic acid at the presence of sulfuric acid as a catalyst. The reaction product was again 2-arylmethylene-5,6-dihydro-4,7-dithia-1,3-indandione.

The main reason why the bi derivatives were not obtained in the reaction of dithiaindandione with aromatic aldehydes was assumed to a higher stability of diketo form of dithiaindandione as compared to that of 1,3-indandione or other cyclic β-diketones which gave bi derivatives [14]. The diketo form of dithiaindandione,

Table 1

Characterization of 2-(X-benzylidene)-5,6-dihydro-4,7-dithia-1,3-indandiones

No.	X	Formula	*M*	Calculated/found				Yield %	M.p. °C	λ_{max}	$(\varepsilon) \cdot 10^3$
				% C	% H	% S	% X				
I	H	$C_{14}H_{10}O_2S_2$		61.29	3.67	23.37		78	194—196	372	52
			304.39	61.23	3.88	23.05					
II	3-Cl	$C_{14}H_9ClO_2S_2$		54.43	2.91	20.77	11.48	88	192—194	378	35.6
			308.81	54.61	3.10	20.86	11.31				
III	4-Cl	$C_{14}H_9ClO_2S_2$		54.43	2.91	20.77	11.48	90	238—240	379	35.4
			308.81	54.35	3.18	20.49	11.20				
IV	3-Br	$C_{14}H_9BrO_2S_2$		47.58	2.54	18.15	22.62	85	193—194	378	44.0
			353.26	47.63	2.63	18.30	22.54				
V	4-Br	$C_{14}H_9BrO_2S_2$		47.58	2.54	18.15	22.62	89	240—241	379	45.5
			353.26	47.36	2.36	18.26	22.75				
VI	3-I	$C_{14}H_9IO_2S_2$		41.90	2.25	16.02	31.71	75	174—176	378	13.8
			400.26	41.83	2.21	16.20	31.50				
VII	4-I	$C_{14}H_9IO_2S_2$		41.90	2.25	16.02	31.71	77	239—241	377.6	41.5
			400.26	42.12	2.38	16.20	31.77				
VIII	4-CH₃	$C_{15}H_{12}O_2S_2$		62.47	4.19	22.24		89	248—249	371	85
			288.39	62.40	4.20	21.90					
IX	3-OCH₃	$C_{15}H_{12}O_3S_2$		59.19	3.97	21.07		95	150—152	377	42.6
			304.39	59.11	3.98	20.94					
X	4-OCH₃	$C_{15}H_{12}O_3S_2$		59.19	3.97	21.07		98	202—204	380	40.4
			304.39	59.17	3.83	20.80					
XI	4-OH	$C_{14}H_{10}O_3S_2$		57.91	3.47	22.09		82	265—267	385	65
			290.36	57.86	3.54	22.16					
XII	4-NH₂	$C_{14}H_{11}NO_2S_2$		58.15	3.81	22.17	4.84	79	228—229	430	65.9
			289.38	58.26	4.00	22.34	4.80				
XIII	4-N(CH₃)₂	$C_{16}H_{15}NO_2S_2$		60.91	4.73	20.64	4.41	79	233—235	454	32.4
			317.43	60.78	4.95	20.38	4.30				
XIV	4-CN	$C_{15}H_9NO_2S_2$		60.26	3.03	21.33	4.66	94	240—245	389	32.4
			300.38	60.31	3.15	21.16	4.54				
XV	3-NO₂	$C_{14}H_9NO_4S_2$		52.96	2.82	20.05	4.39	98	254—256	386	76.0
			319.36	53.12	2.85	19.87	4.15				
XVI	4-NO₂	$C_{14}H_9NO_4S_2$		52.96	2.82	20.05	4.39	99	282—283	393	71
			319.36	52.71	2.95	20.28	4.32				

Table 2

Characterization of 2-(5-X-furfurylidene)-5,6-dihydro-4,7-dithia-1,3-indandiones

No.	X	Formula	*M*	Calculated/found				Yield	M.p.	$\lambda_{\max}$	$(\varepsilon) \cdot 10^3$
				% C	% H	% S	% X	%	°C		
XVII	H	$C_{12}H_8O_3S_2$	264.32	54.53 54.56	3.05 3.26	24.26 24.46		60	175—176	430	18.6
XVIII	Br	$C_{12}H_7BrO_3S_2$	343.22	41.42 41.45	2.05 2.15	18.68 18.69	23.28 23.00	77	262—264	428	25.3
XIX	I	$C_{12}H_7IO_3S_2$	390.22	36.94 36.72	1.81 1.92	16.40 16.82		78	258—260	445	27.6
XX	CH_2Cl	$C_{13}H_9ClO_3S_2$	312.79	49.91 49.85	3.82 3.95	20.58 20.63	11.33 11.21	79	140—142	429	25.5
XXI	NO_2	$C_{12}H_7NO_5S_2$	293.32	48.47 48.53	2.35 2.64	21.82 21.56	4.77 4.80	76	286—287	425	22.4
XXII	CH_3	$C_{13}H_{10}O_3S_2$	278.35	56.09 56.03	3.62 3.71	23.04 22.90		84	169—170	413	32.6
XXIII	SCH_3	$C_{13}H_{10}O_3S_3$	310.42	50.30 50.50	3.25 3.35	30.99 30.85		97	180—182	431	36.0
XXIV	SC_6H_5	$C_{18}H_{12}O_3S_3$	372.49	58.04 58.05	3.25 3.51	25.82 25.55		97	163—164	445	33.0

due to its stability, did not undergo autoaldol condensation and did not give compounds of the bindone type [6].

The electronic spectra of the prepared 2-arylmethylene-5,6-dihydro-4,7-dithia-1,3-indandiones revealed three absorption bands at 370—450 nm ($\varepsilon \cdot 10^3 = 18-85$; Table 1), 260 nm (lower intensity), and 200—210 nm (higher intensity). The position of the band at 370—450 nm was mostly influenced by the nature of the substituent with all compounds. The compounds containing an electron-donating substituent on phenyl in the *p*-position showed a significant bathochromic shift contrary to the compounds with the same substituent in the *m*-position and in all cases they were intensively coloured.

The compounds *I—XXIV* showed two bands in the region of the stretching vibration of carbonyl group belonging to symmetrical and asymmetrical vibration of the C=O group of the β-dicarbonyl system. The i.r. spectra of these compounds have been discussed previously [15].

From aliphatic aldehydes, acetaldehyde and glycolaldehyde were used for the reaction with dithiaindandione. The reaction with acetaldehyde was carried out according to the method used in [2] for 1,3-indandione. Evaluation of the i.r. and p.m.r. spectra showed that dithiaindandione reacted with acetaldehyde in the ratio 2 1 giving *XXV* and with glycolaldehyde in the ratio 1 1 affording *XXVI*.

Dithiaindandione gave different products than indandione also with some ketones. While indandione afforded a complicated product with acetone [12], dithiaindandione reacted with acetone similarly as with aldehydes and gave *XXVII*; its structure was confirmed by i.r. and p.m.r. spectra and its molecular weight by mass spectrometry. The difference in the obtained products was attributed to the fact that indandione underwent autoaldol condensation and then the product reacted with acetone. The reactions of dithiaindandione with methyl ethylketone, cyclopentanone, and cyclohexanone resulted in similar products as with acetone. These reactions proceeded easier than those with 1,3-indandione.

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