

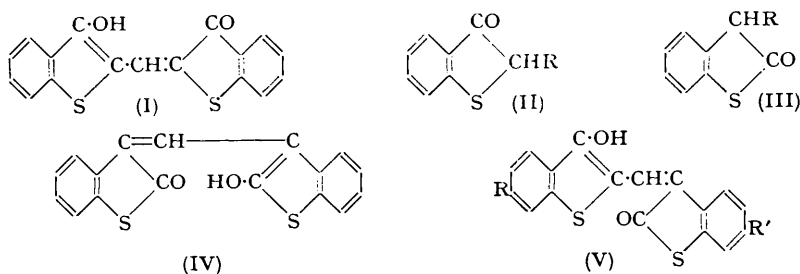
Some Oxonols derived from Thio-oxindole. Part I.

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The symmetrical oxonol derived from thio-oxindole and three unsymmetrical oxonols containing this nucleus have been prepared and their sensitising properties determined. Two of the latter dyes show abnormal behaviour on heating, undergoing isomerisation at their melting points.

Bis-[2-(2 : 3-DIHYDRO-3-OXOTHIONAPHTHEN)]METHINOXONOL (I) was first prepared by Friedländer and Kielbasinski (*Ber.*, 1911, **44**, 3098) who condensed thioindoxyl (II; R = H) with its 2-formyl derivative (II; R = CHO) in the presence of sulphuric acid. It has subsequently been obtained by the reaction of thioindoxyl with chloroform and alkali (Friedländer and Risse, *Ber.*, 1914, **47**, 1919), with formic acid (Schwenk, *J. pr. Chem.*, 1921, **103**, 103; Rodionov, Bogoslovskii, and Kazakova, *Izvest. Akad. Nauk S.S.S.R., Otdel. Khim. Nauk*, 1948, 536; *Chem. Abs.*, 1949, **43**, 2200), and with formamide (Hünig, *Annalen*, 1951, **574**, 99). It is also formed by the interaction of thioindoxyl with thioindoxyl-2-aldehyde anil (II; R = ·CH:NPh) under acid conditions [Sveshnikov and Levkoev, *J. Gen. Chem. (U.S.S.R.)*, 1940, **10**, 274]. Dyes of type (I) have been found



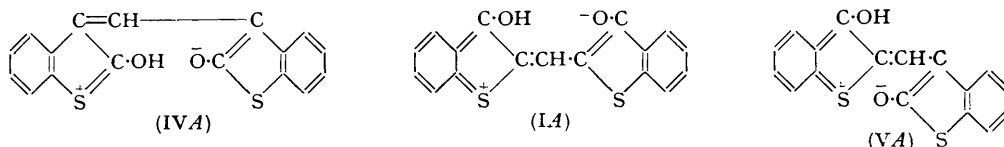
to act as photographic sensitisers for the green portion of the spectrum (Brooker, in Mees, "The Theory of the Photographic Process," Macmillan, London, 1942, p. 990). In view of the marked sensitising action of certain *merocyanines* derived from thio-oxindole (Glauert and Mann, *J.*, 1952, 2135) it was of interest to prepare the isomeric oxonol (IV) containing two thio-oxindole nuclei, and unsymmetrical oxonols of type (V) containing one thioindoxyl and one thio-oxindole nucleus.

We have prepared the bright red bis-[3-(2 : 3-dihydro-2-oxothionaphthen)]methinoxonol (IV) by condensing thio-oxindole (III; R = H) with its 3-formyl derivative (III; R = H)

R = CHO) in the presence of triethylamine. Thio-oxindole-3-aldehyde anil (III; R = $\cdot\text{CH}_2\text{NPh}$) failed however to react with thio-oxindole despite the use of a variety of conditions, and the attempted preparation of (IV) from thio-oxindole and formamide was also unsuccessful although under comparable conditions thioindoxyl gives an almost quantitative yield of the dye (I) (Hünig, *loc. cit.*).

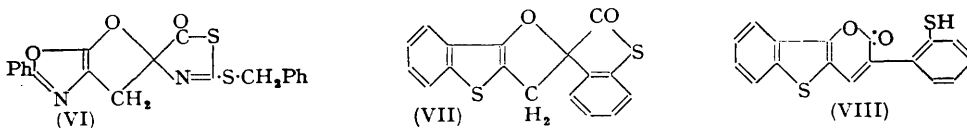
The oxonol (V; R = R' = H) was prepared by condensing thioindoxyl-2-aldehyde anil with thio-oxindole under acid or basic conditions: it could not be obtained by the condensation of thio-oxindole-3-aldehyde with thioindoxyl or by that of thio-oxindole with thioindoxyl and formamide. The deep red crystals melt at 222–223°, resolidify on further heating and remelt at 260–275°; the significance of this behaviour is discussed below.

The symmetrical oxonol (IV) derived from thio-oxindole is markedly more soluble in common solvents than the unsymmetrical dye (V) or the thioindoxyl compound (I); moreover, its absorption maximum, 500 m μ , is at much shorter wave-length than that of (V), λ_{max} 566 m μ , or of (I), λ_{max} 592 m μ . These properties may reflect (a) the greater degree of steric hindrance in (IV) preventing coplanarity of the two nuclei (cf. Knott, *J.*, 1952, 2399), and (b) the absence of *ortho*-quinonoid forms analogous to (IA) and (VA) in bipolar structures, such as (IVA), which must contribute to the resonance hybrid of (IV).



The compound formed from (V; R = R' = H) by the action of heat is an isomer, m. p. 283–284°: its ultra-violet spectrum in dioxan shows λ_{max} 370 m μ , and its infra-red spectrum shows no hydroxyl band. It is insoluble in aqueous alkalis but dissolves in hot ethanolic potassium hydroxide to give a yellow solution which on acidification yields a new compound, m. p. 159°, which in ethanol has λ_{max} 356 m μ , and which contains a hydroxyl group (band at 3.06 μ). This compound is reconverted at its melting point into the above isomer from which it appears on analytical evidence to be derived by addition of one equivalent of ethanol. Neither the compound of m. p. 283–284° nor that of m. p. 159° contains a thiol or a carboxylic acid group.

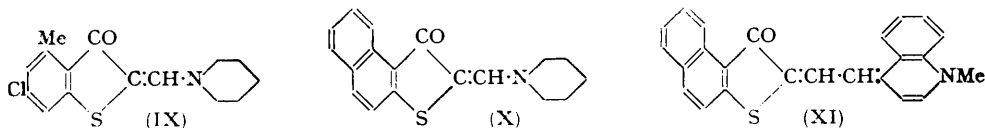
A satisfactory explanation of the above results has not been found. It may be noted that Knott (*loc. cit.*) has observed a somewhat similar but readier isomerism in some oxonols derived from oxazolones, and has suggested the spiran structure (VI) for the isomer of [2-benzylthio-4-thiazol-5-one][2-phenyl-4-oxazol-5-one]methinoxonol. It is unlikely that the isomer of (V; R = R' = H) has the analogous structure (VII), for this



would not be expected to cause absorption at 370 m μ , and it also does not offer a satisfactory interpretation of the reaction with ethanolic potassium hydroxide. A further possibility that the isomer is the *o*-mercaptophenylthionaphthenopyrone (VIII) is precluded by the absence of a thiol group, although such a compound would be expected to undergo ring opening with alkali, with generation of hydroxyl group, and ready recyclisation. The molecular weight of the isomer indicates further that it is not the disulphide corresponding to (VIII). The exact structures of the isomer and its derived product remain obscure, and the small quantities available have prevented a fuller investigation.

We have also prepared oxonols of type (V) with an ethoxy-substituent in either the

thio-oxindole or the thioindoxyl ring. The former dye (V; R = H, R' = OEt) behaved like (V; R = R' = H), undergoing isomerisation at its melting point; the latter, (V; R = OEt, R' = H), however, did not. As the effect of the ethoxy-group in the second case will probably be to suppress the ionisation of the hydroxyl group of the thioindoxyl ring, the result suggests that ionisation of this group is the first stage in the observed isomerisation reaction.



The attempted condensation of 6-chloro-4-methylthioindoxyl-2-aldehyde and thio-oxindole in boiling ethanol containing piperidine gave mainly 6-chloro-4-methyl-2-(piperidinomethylene)thioindoxyl (IX), contaminated with a small amount of a red dye, presumably the required oxonol (as V). It was found moreover that the compound (IX) could be prepared by the direct reaction of the aldehyde and piperidine in ethanol. The fact that compounds of type (IX) can act as intermediates in the preparation of *merocyanines* from hydroxy-aldehydes in the presence of piperidine, as well as in the preparation of oxonols, has been shown by the preparation of the known *merocyanine* (XI) (Glauert and Mann, *loc. cit.*) by the condensation of (X) and lepidine methiodide in boiling ethanol in the absence of a catalyst.

The absorption and sensitising properties of the new oxonols are briefly summarised on p. 33.

EXPERIMENTAL

Thio-oxindole, its 3-aldehyde, and the aldehyde anil were prepared by Glauert and Mann's method (*J.*, 1952, 2127).

Bis[3-(2 : 3-dihydro-2-oxothionaphthen)]methinoxonol (IV).—A solution of thio-oxindole-3-aldehyde (III; R = CHO) (0.5 g.) and thio-oxindole (0.42 g., 1 mol.) in ethanol (10 c.c.) containing triethylamine (0.4 c.c., 1 mol.) was boiled for 3 hr. under reflux and the solvent then evaporated. The residual red gum was stirred and washed with ether (4 × 10 c.c.), and then dissolved in a minimum of hot acetic acid. The *oxonol* (IV) slowly crystallised in red needles, m. p. 162—163°, when recrystallised from acetic acid (Found : C, 65.6; H, 3.5. C₁₇H₁₀O₂S₂ require C, 65.8; H, 3.2%).

[2-(2 : 3-Dihydro-3-oxothionaphthen)][3-(2 : 3-dihydro-2-oxothionaphthen)]methinoxonols (V).—Equimolecular amounts of the appropriate thioindoxyl-2-aldehyde anil and the thio-oxindole, dissolved in the minimum of boiling ethanol, were treated with triethylamine (1 mol.). After 0.5—2 hours' boiling, the dye was worked up as above, ready crystallisation occurring on addition of the acetic acid.

The *oxonol* (V; R = R' = H) formed red needles (36%), m. p. 222—223°, when inserted at 210°, resolidifying on further heating to 230° and remelting at 260—275° (Found : C, 65.7; H, 2.95. C₁₇H₁₀O₂S₂ requires C, 65.8; H, 3.2%). The use of a small quantity of hydrochloric acid as catalyst in place of triethylamine gave the same product.

The *oxonol* (V; R = H, R' = OEt) formed clusters of red-brown prisms (43%), m. p. 179—181° when inserted at 165°, resolidifying by 185° and remelting at 250—257° (Found : C, 64.5; H, 4.3. C₁₉H₁₄O₃S₂ requires C, 64.4; H, 4.0%). A second sample melted only when inserted at *ca.* 195—200°, resolidifying in 1 min. at this temperature and remelting at 250—257° (Found : C, 64.3; H, 4.4%). The infra-red spectra of the two samples were indistinguishable.

Condensation of 6-ethoxy(thioindoxyl) and *NN'*-diphenylformamidine in boiling ethanol (15 min.) gave 6-ethoxy(thioindoxyl)-2-aldehyde anil as orange-brown crystals, m. p. 144°, from cyclohexane (Found : C, 69.0; H, 5.2. C₁₇H₁₅O₂NS requires C, 68.6; H, 5.1%). The *oxonol* (V; R = OEt; R' = H) formed chocolate-coloured crystals (34%), m. p. 206°, unchanged on further heating to 300° (Found : C, 64.5; H, 4.2. C₁₉H₁₄O₃S₂ requires C, 64.4; H, 4.0%).

Isomer of the Oxonol (V; R = R' = H).—The oxonol (570 mg.) was heated in an oil-bath for 10 min. whilst the temperature was raised from 225° to 235°. The dye melted with mild effervescence and some yellowish oil formed in the upper part of the tube. The residue,

dissolved in hot glacial acetic acid (125 c.c.), on cooling deposited dark crystals (315 mg.), m. p. 270—273°, which when recrystallised from the same solvent gave purple-brown crystals, m. p. 276—278° (Found: C, 65.85; H, 3.0%). A dark impurity was removed by chromatography of a benzene solution of the product on alumina, and recrystallisation from ethanol then gave the *isomer* as pale fawn needles, m. p. 283—284° (Found: C, 65.8; H, 3.1%; *M*, cryoscopically in ethylene dichloride, 300. $C_{17}H_{10}O_2S_2$ requires C, 65.8; H, 3.2%; *M*, 310). Solutions of the product in ethanol or benzene were fluorescent. A solution in dioxan showed λ_{max} 370 m μ , (ϵ 23,900); 389 m μ , (ϵ 18,500). The infra-red spectrum showed a carbonyl band at 5.78 μ but no hydroxyl or thiol bands.

This *isomer* (80 mg.) was boiled with potassium hydroxide (1 g.) in ethanol (20 c.c.) for 2 min., giving a yellow-brown solution which, when cooled, diluted with water (40 c.c.), and acidified with dilute hydrochloric acid gave a fawn-coloured precipitate. Recrystallisation from ethanol-water and then ethanol gave a *compound* as very pale yellow crystals, m. p. 159°, when inserted at 150°, resolidifying and remelting at *ca.* 285° (Found: C, 64.2, 64.3; H, 4.6, 4.6. $C_{19}H_{16}O_3S_2$ requires C, 64.0; H, 4.5%. $C_{28}H_{20}O_6S_4$ requires C, 64.2; H, 4.3%). The ultra-violet spectrum in ethanol showed λ_{max} 356 m μ (ϵ 13,500), and in ethanol containing a small quantity of sodium hydroxide 402—405 m μ (ϵ 7380). The infra-red spectrum showed a hydroxyl band at 3.06 μ and a carbonyl band at 5.91 μ , but no thiol band.

Isomer of the Oxonol (V; R = H; R' = OEt).—The oxonol was heated for 10 min. at 200—230° and the product worked up as above, giving very pale brown prisms with a dark reflex, m. p. 262—263°, apparently the *isomer* (Found: C, 64.0, 63.9; H, 3.45, 3.7. $C_{19}H_{14}O_3S_2$ requires C, 64.4; H, 4.0%). In dioxan solution it showed λ_{max} 378 (ϵ 28,900), 397 m μ (ϵ 22,900).

Attempted Condensation of 6-Chloro-4-methylthioindoxyl-2-aldehyde with Thio-oxindole.—When an ethanolic solution of equimolecular amounts of the aldehyde, thio-oxindole, and piperidine was boiled under reflux for 6 hr. and cooled, the precipitate consisted largely of grey-green lumps, m. p. 191—194°, contaminated with a trace of red material. Recrystallisation from aqueous acetic acid gave the dye (IX), m. p. 195—197°, undepressed on admixture with the following authentic compound.

6-Chloro-4-methyl-2-(piperidinomethylene)thioindoxyl (IX) was formed readily when an ethanolic solution of 6-chloro-4-methylthioindoxyl-2-aldehyde and piperidine (1 mol.) was boiled for 6 hr. The product (58%) separated on cooling and gave yellow needles, m. p. 200—202°, from ethanol (Found: C, 61.3; H, 5.4; N, 5.1. $C_{15}H_{14}ONClS$ requires C, 61.3; H, 5.45; N, 4.8%).

Mixing an ethanolic solution of this compound with an ethanolic solution of 2:4-dinitrophenylhydrazine containing some hydrochloric acid caused the slow deposition of the 2:4-dinitrophenylhydrazone of 6-chloro-4-methylthioindoxyl-2-aldehyde, m. p. 257—258°, undepressed on admixture with an authentic sample.

2-(Piperidinomethylene)-4:5-benzothioindoxyl (X), similarly prepared (77%) from 4:5-benzothioindoxyl-2-aldehyde, formed sparkling yellow plates, m. p. 190—191° (Found: C, 73.0; H, 5.8; N, 5.0. $C_{18}H_{17}ONS$ requires C, 73.2; H, 5.8; N, 4.7%). The infra-red spectrum showed a carbonyl band at 6.1 μ , and no NH band.

When an ethanolic solution of this compound and lepidine methiodide (1 mol.) was boiled for 7 hr., a deep green colour developed with deposition of the crystalline [2-(2:3-dihydro-3-oxo-4:5-benzothionaphthen)][4-(1:4-dihydro-1-methylquinoline)]dimethinmerocyanine (XI), m. p. 285—287°, unaffected on admixture with an authentic sample; it gave a turquoise-coloured ethanolic solution.

Absorption and Sensitisation Data.—In the following Table, columns 2, 3, and 4 give the absorption maxima of the oxonols in ethanol, 2-ethoxyethanol containing a small amount of methanolic sodium hydroxide, and 2-ethoxyethanol containing a small amount of hydrochloric acid, respectively. Column 5 gives the absorption maxima in a positive chlorobromide emulsion and column 6 the sensitisation range in this emulsion. Figures are in m μ .

Oxonol	Absorption maxima			Max. in emulsion	Range
(I)	592	587	482	600	470—655
(IV)	500	500	430	515	(470)—550
(V; R = R' = H)	566	566	465	580	(465)—635
(V; R = H, R' = OEt)	578	580	—	565	460—630
(V; R = OEt, R' = H)	490, 512	550	482	600	(480)—645

In positive emulsions, the sensitising power of the first three oxonols decreases in the order (I) > (V; R = R' = H) > (IV), in agreement with the expectation on steric grounds; that

of (V; R = H, R' = OEt) is markedly less than that of (V; R = OEt, R' = H). All show only low sensitisation in negative emulsions.

We are greatly indebted to Imperial Chemical Industries Limited, Dyestuffs Division, for the above investigation of the absorption and sensitisation of the oxonols, and to the Department of Scientific and Industrial Research for a grant (to A. J. W.).

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