73. *The Comparative Reactivity of the Carbonyl Groups in the Thionaphthenquinones. Part I. The Constitution of Certain Thioindigoid Dyes.*

By John Harley-Mason and Frederick G. Mann.

In view of the scanty and conflicting evidence hitherto available, an investigation has been made of the factors determining the type of condensation of the thioindoxyls with the thionaphthenquinones, *i.e.*, whether the methylene group of the former reacted with the α-carbonyl group of the latter to give a thioindigo or with the β-carbonyl group to give a thioindirubin. For this purpose, thioindoxyl and six substituted thioindoxyls have been condensed with the corresponding thionaphthenquinones, and the product in each case compared with that obtained by the condensation of the thioindoxyl with the corresponding α-anil, where α-condensation must necessarily have occurred. The results show that the condensation in most cases is determined solely by the position of substituents in the quinone molecule and is unaffected by those in the thioindoxyl molecule : thionaphthenquinone and 5- or 6-substituted thionaphthenquinones always give β-condensation, 4-substituted quinones always give α-condensation, and 7-substituted quinones may give α- or β-condensation : only with the last quinones, therefore, is the type of condensation affected by the thioindoxyl employed.

Indoxyl and oxindole, however, always give β- and α-condensation respectively with all the thionaphthenquinones investigated, the effect of these two compounds being thus to suppress completely the influence of substituents in the quinone molecule. The significance of these results is discussed.

It is known that compounds containing reactive methylene groups, such as indoxyl and thioindoxyl,* always condense with the 3- or β-carbonyl group of the isatin molecule : the reaction with thioindoxyl (I)

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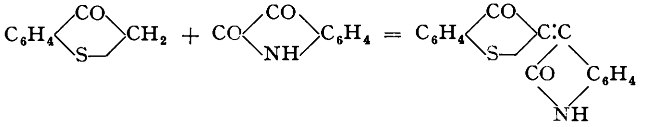
* This compound is correctly named 3-hydroxythionaphthen, but since in all the reactions cited in this paper it is reacting in the keto-form, it should systematically be termed 3-keto-2 : 3-dihydrothionaphthen. For brevity, however, and in accordance with common practice, the term thioindoxyl has been used throughout.

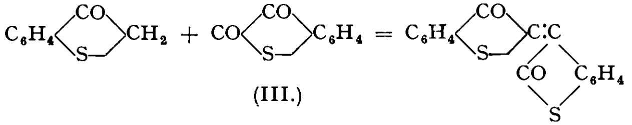
therefore gives the 2 : 3′-derivative (II). The non-reactivity of the 2- or α-carbonyl group of the isatin molecule is probably due to the fact that this compound reacts predominantly in the enol or lactim form.

(I.)



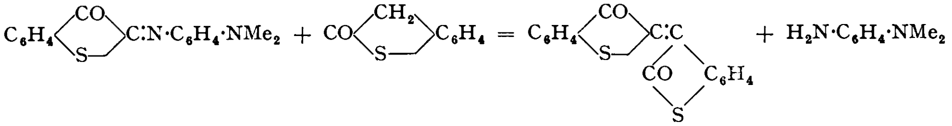
(II.)

In similar condensations with thionaphthenquinone (III), which cannot show this type of tautomerism, the scanty evidence available showed that the β-carbonyl group did not possess this markedly greater reactivity over the α-carbonyl group. Indoxyl and thioindoxyl, *e.g.*, condense with the β-carbonyl group of thionaphthenquinone (Friedländer, *Monatsh.* 1908, **29**, 373, 375): the structure of the dye thus obtained from indoxyl

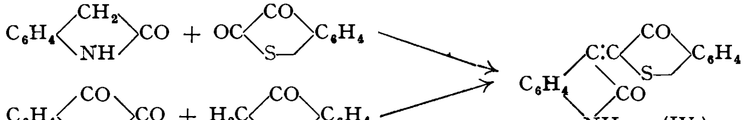


(III.)

was proved by its alkaline fission products (Friedländer *et al.*, *Ber.*, 1910, **43**, 1971; 1911, **44**, 3107); that of the dye from thioindoxyl was proved by the fact that the same dye could be prepared by the condensation of



the *p*-dimethylaminoanil of thioindoxyl with thio-oxindole (Marschalk, *J. pr. Chem.*, 1913, **88**, 227). On the other hand, there have been several examples cited (mainly in patent literature) in which similar reactions involve the α-carbonyl group of the quinone molecule. For example, thioindigo scarlet (IV) is obtained by the condensation of oxindole with thionaphthenquinone and by the condensation of isatin with

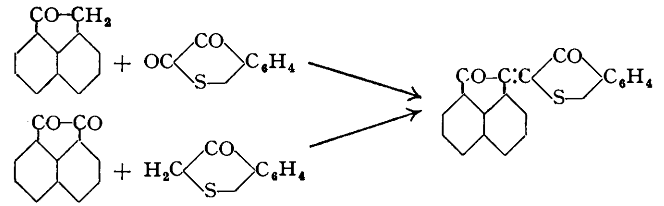


(IV.)

thioindoxyl (E.P. 214,864). Similarly, it has been claimed that identical products are obtained by the condensation of acenaphthenone (V) with thionaphthenquinone and of acenaphthenquinone (VI) with thioindoxyl (D.R.-P. 205,377, 226,244): this would indicate that here again the α-carbonyl group of the quinone

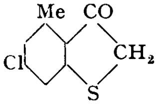
(V.)

(VI.)

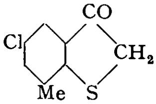


molecule has undergone condensation. Several other similar examples could be given (*e.g.*, E.P. 214,864, 222,094, 232,230).

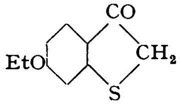
Although the condensation of substituted thioindoxyl and similar compounds with substituted thionaphthenequinones is largely used in dye manufacture, the true constitution of the dye—dependent upon whether the α-carbonyl group of the quinone has condensed to give an indigo or the β-carbonyl group condensed to give an indirubin—has usually been either assumed without evidence or else ignored. The object of the present investigation was therefore to carry out a number of such condensations, to determine the structure of the products, and thus if possible to determine also the factors which control the reactivity of the α- and β-carbonyl groups in the quinone.



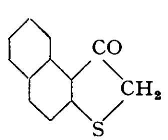
(I*b*.)



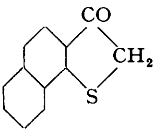
(I*c*.)



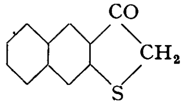
(I*d*.)



(I*e*.)



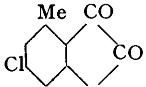
(I*f*.)

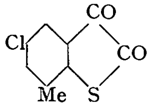


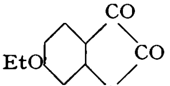
(I*g*.)

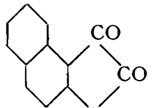
For this purpose, the following thioindoxyls were used, these compounds being chosen because they could be readily prepared from technical materials: thioindoxyl (I); 6-chloro-4-methylthioindoxyl (I*b*); 5-chloro-

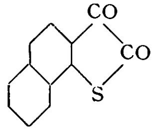
7-methylthioindoxyl (I*c*); 6-ethoxythioindoxyl (I*d*); 4 : 5-benzthioindoxyl (I*e*) *; 6 : 7-benzthioindoxyl (I*f*); 5 : 6-benzthioindoxyl (I*g*). These compounds were condensed with *p*-nitrosodimethylaniline to give the anils, and the latter on hydrolysis gave the corresponding quinones: in this way, thionaphthenquinone (III) and the substituted quinones (III*b*—III*g*) were prepared.

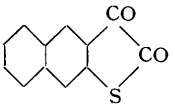

(III*b*.)


(III*c*.)

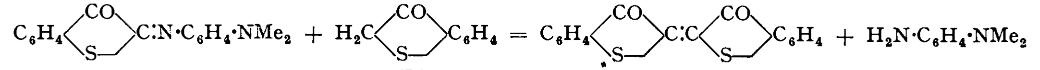

(III*d*.)


(III*e*.)


(III*f*.)


(III*g*.)

The various thioindoxyls were then condensed with each of the quinones, and the product in each case compared with that obtained by the interaction of the thioindoxyl with an anil. In the latter reaction, condensation to a dye must occur at the 2- or α-carbon atom, and such compounds were therefore used as reference

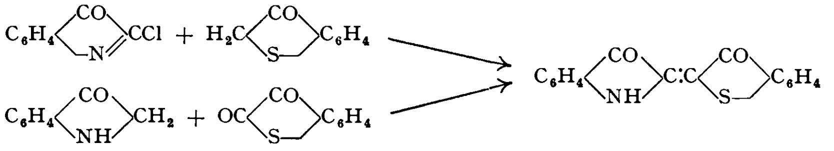

(I.) (VII.)

$$C_6H_4\left<\begin{matrix}CO\\S\end{matrix}\right>C{:}N{\cdot}C_6H_4{\cdot}NMe_2 + H_2C\left<\begin{matrix}CO\\S\end{matrix}\right>C_6H_4 = C_6H_4\left<\begin{matrix}CO\\S\end{matrix}\right>C{:}C\left<\begin{matrix}CO\\S\end{matrix}\right>C_6H_4 + H_2N{\cdot}C_6H_4{\cdot}NMe_2$$

compounds of known structure. If the product of condensation of the thioindoxyl and the quinone were identical with the product from the anil, then clearly the α- or 2-carbonyl group of the quinone had undergone condensation: if the compounds were different, then the β- or 3-carbonyl group of the quinone had reacted.

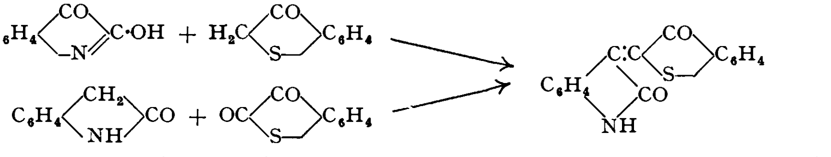
In certain cases, the reference compound having the 2 : 2′-structure could be made more expeditiously than through the anil intermediate. Thus symmetric derivatives such as (VII) could also be prepared by direct oxidation of the thioindoxyl (I) with alkaline ferricyanide.

In addition to the use of the thioindoxyls (I—I*g*), indoxyl and oxindole were also condensed with the quinones (III—III*g*), in order to determine whether the presence and position of the nitrogen atom in place of the sulphur would markedly affect the type of condensation obtained. For the indoxyl condensation, reference compounds of known structure were prepared by the condensation of isatin chloride with the



required thioindoxyl: the product must clearly be identical with that which would be obtained if indoxyl condensed with the α-carbonyl group of thionaphthenquinone.

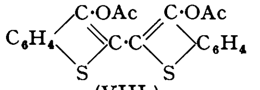
For the oxindole condensation, reference compounds were prepared by the condensation of isatin and thioindoxyl, whereby a product was obtained identical with that which would result from the condensation

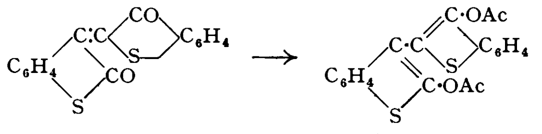


of oxindole with the α-carbonyl group of thionaphthenquinone. The structure of these reference compounds was further confirmed by the preparation of identical compounds by the condensation of oxindole with the anils obtained from the thioindoxyls.

In all the cases examined, therefore, a pair of compounds, one being a reference compound of known structure, was obtained: these compounds were usually deeply coloured, of high or indefinite m. p., and of very low solubility in most organic solvents. The means adopted to decide whether the members of each pair were identical or different must now be discussed.

1. *Reductive Acetylation.*—Friedländer (*Monatsh.*, 1908, **29**, 373) has shown that the compound (VII), when treated with zinc dust in boiling acetic acid–acetic anhydride, is converted into the diacetyldihydro-


(VIII.)

(IX.)

(X.)

derivative (VIII). We find that this reaction is of wide application; *e.g.*, the isomeric thioindirubin (IX) similarly gives the diacetyl-dihydro-derivative (X). These derivatives from both classes are usually highly

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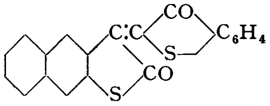
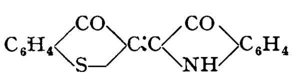
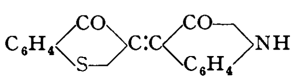
* Compounds of this type have frequently been named " naphthathioindoxyl " or " naphtha-3-hydroxythionaphthene " : these names are clearly incorrect, as they imply the existence of three fused benzene rings. The term " 4 : 5-benzthioindoxyl " has been adopted for greater accuracy and particularly to emphasise the position of the substituents in the main benzene ring.

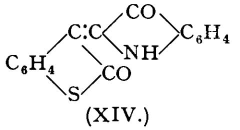
crystalline, sparingly soluble compounds of sharp m. p., and this reductive method has proved the most valuable of the chemical methods available for the characterisation and identification of the original dye. The diacetyl-dihydro-derivatives of the thioindirubins were always more soluble and had lower m. p.'s than the corresponding thioindigo derivatives.

This reductive method cannot be applied, however, to all types of compound prepared in this investigation: diacetyl-dihydro-derivatives were not obtained from thioindirubins of type (XI) containing one linear naphthalene residue, or from the mixed sulphur-nitrogen compounds of types (XII), (XIII), and (XIV), which appeared to undergo fission at the double bond.


(XI.)

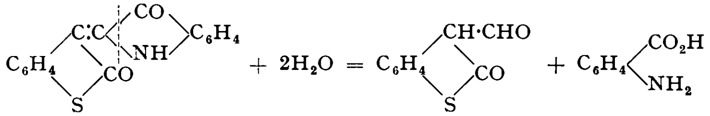

(XII.)


(XIII.)

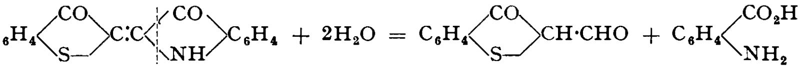

(XIV.)

2. X-*Ray Analysis.*—The dyes, after recrystallisation from boiling nitrobenzene or acetic anhydride, lend themselves readily to *X*-ray photography by the "powder" method, which therefore affords an excellent method of comparing the identities of each pair of substances. This work has been kindly undertaken by Dr. W. H. Taylor and Dr. A. Hargreaves of the Physics Department of the Manchester College of Technology. Their results concerning the identity of the thioindoxyl condensation products agree with our results, apart from two pairs of substances (see Tables VI and VII) where our diacetyl-dihydro-derivatives had m. p.'s too high for reliable comparison and where therefore the *X*-ray evidence alone was available. The *X*-ray work has thus afforded a valuable and entirely independent confirmation of our chemical methods of comparison.

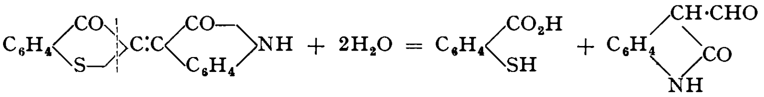
3. *Alkali Fission.*—Friedländer (*loc. cit.*) has applied this reaction to the unsubstituted thio-indigos and -indirubins. We find, however, that substituted derivatives of each class are very resistant to alkali, and this reaction has been applied, therefore, only to compounds of type (XII), (XIII), and (XIV), to which reductive acetylation cannot be applied. Thus compounds of type (XIV) are readily decomposed by alkali to


(XIV.) (XV.)

give anthranilic acid and the thio-oxindole-3-aldehyde (XV). Compounds of type (XII) break down less readily, giving anthranilic acid and thioindoxyl-2-aldehyde (XVI). These aldehydes form well-crystallised phenylhydrazones, and a number have thus been characterised.


(XII.) (XVI.)

Compounds of type (XIII) decompose still less readily with alkali, giving a thiosalicylic acid and oxindole-3-aldehyde (XVII). Since, however, the isolation of the substituted thiosalicylic acids proved difficult,


(XIII.) (XVII.)

alkali-splitting of compounds of type (XIII) has not been extensively employed, and the comparison of the oxindole condensation products with their reference compounds has therefore been made throughout by *X*-ray analysis.

4. *Dyeing Tests.*—The members of each pair of compounds could be compared by carrying out dyeing tests on cotton under strictly controlled and parallel conditions. This method proved satisfactory for those compounds which underwent vatting without decomposition. Some compounds proved too unstable: *e.g.*, thioindirubins having substituents in only one benzene ring were almost completely broken down during vatting and were thus almost useless as dyes, whereas similar compounds having substituents in both rings were stable to vatting and formed moderately good dyes, being usually weaker and paler than the corresponding thioindigos.

5. *Colours of Sulphuric Acid Solutions.*—All the dyes prepared in this work, when dissolved in cold concentrated sulphuric acid, gave intense colours entirely different from those of the parent dyes. Since, however, the colour of these solutions was much affected by traces of impurities, this test was employed only when markedly different colours produced by two compounds in solution proved their non-identity. The use of this test was therefore solely confirmatory to certain results obtained by previous tests.

The detailed data provided by these five tests are discussed later. The final conclusion so obtained for the identity of each compound prepared by the condensation of the thioindoxyl (or other $>CH_2$ compound) with the thionaphthenquinone is given in Table I, and may conveniently be discussed here. Not every member has been prepared, as this would have involved the preparation and critical examination of over 120 compounds : sufficient have been made to show beyond reasonable doubt how each quinone condenses with the various cyclic methylene compounds employed. It should be emphasised that no example of a mixture of α- and β-condensation products arising in one reaction was found, in spite of a very close scrutiny which, we consider, would have detected the second isomeric form had it constituted more than 5% of the product : each reaction therefore appeared to give solely α- or β-products.

If the condensation products of the quinones with the various thioindoxyls alone are first considered, the results in Table I indicate clearly : (i) Thionaphthenquinone and all derivatives having substituents solely in the 5- or the 6-position or both (*i.e.*, III, III*d*, III*g*) condense only with the β-carbonyl group, irrespective of the nature of the thioindoxyl employed. [In compounds such as (III*g*) the second benzene ring fused on to the main ring is regarded as two substituent groups.]

(ii) Thioquinones having a substituent in the 4-position (III*b*, III*e*) condense only with the α-carbonyl group, and this behaviour is apparently unaffected by other substituents in the benzene ring.

Table I.

	(III.)	(III*b*.)	(III*c*.)	(III*d*.)	(III*e*.)	(III*f*.)	(III*g*.)
(I.)	β	α	α		α	α	β
(I*b*.)	β	α		β	α		
(I*c*.)			α	β	α	α	β
(I*d*.)	β	α	α	β	α	β	β
(I*e*.)	β	α	α		α	β	β
(I*f*.)	β	α	β	β	α	α	β
(I*g*.)	β	α	α	β	α	α	β
Indoxyl ...	β	β	β	β	β	β	β
Oxindole	α	α	α	α	α	α	α

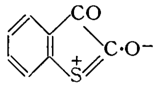
(iii) Thioquinones having a substituent in the 7-position (III*c*, III*f*) condense with the α- or the β-carbonyl group, according to the thioindoxyl employed : the 7-substituent appears thus to have no decisive influence. In view of this fact it is particularly noteworthy that even in these reactions, a mixture of α- and β-products from one pair of reactants was never detected.

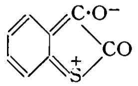
It is remarkable, therefore, that, whereas the nature of the condensation product in the examples (i) and (ii) above appears to be determined solely by the substituents in the thionaphthenquinone molecule, the completely reverse effect is found when indoxyl and oxindole condense with these quinones. Here it will be seen (Table I) that indoxyl gives solely β-condensation and oxindole solely α-condensation irrespective of the thioquinone employed, the effect of the nitrogenous molecule in each case being sufficiently strong to over-ride any influence exerted by the quinone molecule itself.

These results correct certain previous inaccuracies. Thus Dutta (*Ber.*, 1934, **67**, 1324) has indicated that the thioindoxyl (I*g*) condenses with the β-carbonyl group of both quinones (III*e*) and (III*f*) : it is now shown that both these quinones give α-condensation with (I*g*).

It is impossible at present to explain with any degree of certainty the theoretical basis of the results summarised in Table I : these results will have to be extended to many other substituted thioindoxyls and quinones before the experimental data are sufficiently extensive to warrant reliable generalisations. Certain theoretical points should, however, be noted. It has already been pointed out that the exclusive β-condensation of isatin can be explained on its tautomeric nature, but that such tautomerism is impossible with thionaphthenquinone. Nevertheless the latter must be a resonance hybrid between the conventional form (III) and the polar structures (XVIII*a*) and (XVIII*b*). It is possible that of these polar structures the form (XVIII*a*), in which the poles are nearest together, will predominate, and this may be the reason for the greater reactivity of the β-carbonyl group in the unsubstituted thionaphthenquinone. The introduction of substituents into the benzene ring (and hence of further dipoles) will change the nature of the resonance hybrid relative to the parent forms, and hence change also the relative reactivity of the two carbonyl groups. The correlation of the nature and position of such substituents with proportionality of the resonance hybrid cannot yet be made.

(XVIII*a*.)

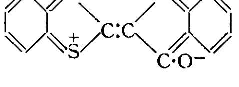


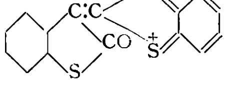


(XVIII*b*.)

A second factor may arise. It has been shown by Ries and Schneider (*Z. Krist.*, 1928, **68**, 543) by *X*-ray analysis that the indigo molecule has a centre of symmetry : this is to be expected if the molecule exists as a resonance hybrid between the normal form and Kuhn's polar form (*Naturwiss.*, 1932, **20**, 618), in which the molecule would be most stable when opposite poles are at a minimum distance apart. Similar considerations apply to thioindigo; this undoubtedly exists as a hybrid between the normal form (VII) and the polar structure (VII*a*), which therefore probably exists also as the more stable *trans*-form, although there is at present no experimental evidence available on this point. Similarly the isomeric thioindirubin may exist as a hybrid between the form (IX) and the polar form (IX*a*), although here a symmetric (and presumably more

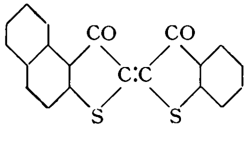
(VII*a*.)





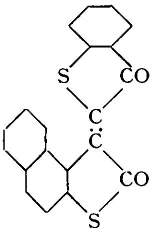
(IX*a*.)

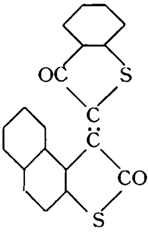
stable) polar structure cannot be achieved. It follows, however, that the existence of resonance in both thio-indigo and thio-indirubin will alter the normal inter-atomic distances and atomic sizes, the true values of which are therefore unknown. This is unfortunate, since lack of this knowledge makes it impossible to say decisively whether in certain cases the results summarised in Table I may not be due partly to steric hindrance. Thus it is noteworthy that the quinone (III*e*) always condenses with thioindoxyls by its α-carbonyl group, *i.e.*, with thioindoxyl itself the compound (XIX) is readily formed, whereas the *cis*- or *trans*-forms of the β-product (XX*a* and XX*b*) apparently do not exist. There is a possibility of steric hindrance in both the latter compounds (greater in XX*b* than XX*a*), and this factor may be partly responsible for the fact that substituents in the 4-position cause condensation solely at the α-carbonyl group, whereas those in the 7-position (where steric hindrance is impossible) are without decisive effect.



(XIX.)

(XX*a*.)



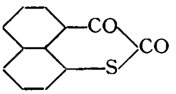


(XX*b*.)

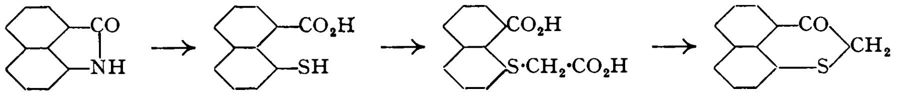
It must be admitted, however, that neither of the above factors (the hybrid structure of the quinone or the steric factor in the condensation product) affords a reasonable explanation why indoxyl itself condenses solely with the β-carbonyl group, and oxindole solely with the α-carbonyl group, of all the thioquinones studied.

We are now engaged in the preparation of thioindoxyls and thionaphthenquinones having substituents solely in the 4- and in the 7-positions in order to widen the scope of our experimental data regarding these condensations.

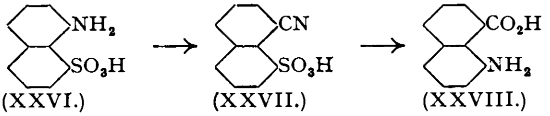
Apart from the main investigation described above, certain other results should be noted. The condensation of the various thioindoxyls (I—I*g*) with 1-*peri*-naphthathiopyran-2 : 3-dione (XXI) would be of great interest, as the latter compound, although isomeric with the quinones (III*e*, III*f*, and III*g*), differs from them in having a 6-membered quinone ring. The corresponding thiopyran-3-one (XXV), corresponding to the thioindoxyls, has been synthesised by Friedländer and Woroshow (*Annalen*, 1912, **388**, 1) by converting naphthastyril (XXII) by the action of nitrous acid and potassium xanthate into the thiol-carboxylic acid (XXIII), condensing the latter with chloroacetic acid to the dicarboxylic acid (XXIV), and cyclising the latter with loss of carbon dioxide to give the required derivative (XXV). We have repeated this synthesis with great difficulty : the purification of the acid (XXIV) proved laborious and wasteful, and the yield of the final product (XXV) was very low. Although the investigation of (XXV) was in consequence abandoned, the various methods for the preparation of naphthastyril (XXII) have been critically examined. The earliest method, consisting in the reduction of 8-nitro-1-naphthoic acid, was not examined in detail, owing to the difficulty of obtaining this acid free from isomerides. The Hofmann degradation of 1 : 8-naphthalimide (Ullmann and Cassirer, *Ber.*, 1910, **43**, 440; Pisovschi, *Bull. Soc. chim.*, 1911, **9**, 87) gave very low yields. The best method consisted in the conversion of 1-naphthylamine-8-sulphonic acid (XXVI) by Sandmeyer's reaction (D.R.P., 444,325) into the 1-cyano-acid (XXVII), which on potash fusion gave the 8-amino-1-naphthoic acid (XXVIII) (E.P. 276,126) : the yield of the naphthastyril (XXII) thus obtained from the *peri*-acid (XXVI) was 60%.



(XXI.)

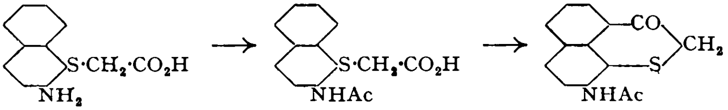


(XXII.) (XXIII.) (XXIV.) (XXV.)



(XXVI.) (XXVII.) (XXVIII.)

Certain substituted derivatives of (XXV) were also investigated. The conversion of sodium 2-naphthylamine-1-thioglycollate (XXIX) in aqueous solution by acetic anhydride into the acetamido-compound (XXX) (D.R.-P. 408,021) has been improved : this reaction must be performed in aqueous solution, since treatment

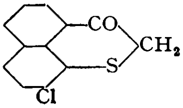


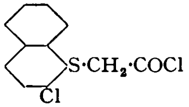
(XXIX.) (XXX.) (XXXI.)

of the sodium salt with acetic anhydride causes rapid cyclisation to the very stable unacetylated lactam, the free acid being apparently incapable of existence. The isolation of 9-acetamido-1-*peri*-naphthathiopyran-3-one (XXXI), after cyclisation of the 2-acetamido-compound (XXX) with chlorosulphonic acid (D.R.-P. 414,084), failed, however, in spite of wide variation in the conditions employed : in these circumstances the $>CH_2$ group in (XXXI) always underwent oxidation, with consequent formation of the thioindigoid dye.

9-Chloro-1-*peri*-naphthathiopyran-3-one (XXXII) is cited in D.R.-P. 362,551, but its preparation is not mentioned. 2-Naphthylamine-1-thioglycollic acid (XXIX) was therefore converted by Sandmeyer's reaction

(XXXII.)





(XXXIII.)

into the 2-*chloro-acid*, and the latter converted into the acid chloride (XXXIII). Cyclisation of the latter to the thiopyran-3-one (XXXII) by the action of aluminium chloride in chlorobenzene was, however, always accompanied by oxidation, with the consequent formation of the corresponding thioindigo. Chlorosulphonic acid, used under various conditions, either left the chloride (XXXIII) unchanged or gave small yields of the thioindigo. In these circumstances, work on the *peri*-derivatives has been temporarily abandoned.

Although the condensation of acenaphthenone with various substituted thioquinones to give good dyes has been claimed (D.R.-P. 463,001, E.P. 189,782, 214,864, 236,332), we find that acenaphthenone condensed with the quinones (III—III*g*) to give brown products that were obviously mixtures and almost useless as dyes. In particular, the claim to prepare 2-thionaphthene-acenaphthene-indigo by condensation with thionaphthenequinone itself (see p. 405) could not be confirmed. Since, moreover, the preparation of pure acenaphthenone is a long and wasteful process, the products of this type of condensation were not further investigated.

EXPERIMENTAL.

Several of the following compounds, whose preparation has been claimed in patent literature without proof of identity, are now recorded as new.

Solvents used for recrystallisation are named in parenthesis after the compounds concerned.

With regard to the *X*-ray results, Dr. Taylor and Dr. Hargreaves report : " Pairs of dyes have been examined in an attempt to decide whether the two individuals of each pair are identical. For this purpose, powder photographs have been taken with (filtered) Kα radiation in a camera of diameter 19 cm.

" Using carefully purified samples of the dyes, the conclusions to be drawn from a comparison of the powder photographs of two compounds are :

(1) If the photographs are identical, then both the structures of the molecules of each compound, and also the packing of the molecules in the crystal, must be identical.

(2) If the photographs are completely different, then either the structures of the molecule are different, or (less likely) the mode of packing is different although the structures of the molecules themselves are identical. Since there is no simple means of distinguishing between these alternatives, *X*-ray powder photographs do not provide an unequivocal solution to the problem."

In the following Tables the abbreviations " Id." and " Non-id." indicate results obtained in (1) and (2) respectively.

Preparation of Intermediates.—Thioindoxyls. All the thioindoxyls except (I*f*) and (I*g*) were obtained from technical sources and purified. The thioindoxyl (I*f*) was obtained from β-naphthylamine by the Herz sulphur chloride method (D.R.-P. 367,344). The thioindoxyl (I*g*) was prepared as follows : Sodium hydroxide (22 g.), 2-amino-3-naphthoic acid (93 g.), and sodium nitrite (36 g.) were dissolved in turn in water (1 l.), and the solution run slowly into a well-stirred mixture of concentrated hydrochloric acid (170 c.c.) and ice (300 g.). The diazo-solution was neutralised with sodium carbonate (Congo-red) and run into a solution of sodium disulphide, prepared from sodium sulphide nonahydrate (60 g.) and sulphur (8 g.) in water (150 c.c.), with vigorous stirring at 25°. The solution was slowly heated to 80°, and sodium hydrosulphite (30 g., an excess) added, the solution being kept alkaline to phenolphthalein. To the solution of sodium 2-thiol-3-naphthoate thus obtained was added a solution of chloroacetic acid (80 g.) and sodium hydroxide (40 g.) in water (300 c.c.) ; the mixture after filtration was maintained at 90° for 1 hour. After cooling, addition of hydrochloric acid precipitated 3-*carboxynaphthyl*-2-*thioglycollic acid*, which was isolated in white crystals (alcohol-benzene), m. p. 175—176° (Found : C, 57·6 ; H, 3·7. $C_{13}H_{10}O_4S$ requires C, 57·8 ; H, 3·6%). The crude acid from the precipitation was stirred into a solution of sodium hydroxide (200 g.) in water (50 c.c.) at 140° ; after 1 hour at 130—140°, the melt was dissolved in hot water, and the thioindoxyl (I*g*) precipitated from the filtered solution with hydrochloric acid at 90° as a greenish-yellow microcrystalline powder (87 g.).

Anils and thionaphthenquinones. The preparation of the *p*-dimethylamino-anils of the thioindoxyls (I—I*e*) and of (I*g*) and their hydrolysis to the corresponding quinones have been described by Mayer *et al.* (*Annalen*, 1931, **488**, 259). The preparation of the *p*-hydroxy-anils from the thioindoxyls was also examined, and only those from (I), (I*d*), and (I*g*) could be satisfactorily prepared. To an alkaline solution of thioindoxyl (30 g. ; sodium hydroxide, 20 g. ; water, 300 c.c.) at 50°, a solution of *p*-nitrosophenol (26 g.) and sodium hydroxide (20 g.) in water (300 c.c.) was added. After 1 hour, sodium chloride (100 g.) was added, and the sodium salt collected. A portion, treated with dilute acetic acid, gave thionaphthenquinone-2-*p*-hydroxyanil (*n*-butyl alcohol), m. p. 251—252° ; Mayer (*loc. cit.*) obtained it as a by-product when preparing the *p*-dimethylamino-anil. 6-*Ethoxythionaphthenquinone*-2-p-*hydroxyanil*, similarly prepared from the thioindoxyl (I*c*) (30 g.) and *p*-nitrosophenol (21 g.), formed brownish-yellow needles (glycol monoethyl ether), m. p. 237—239° (Found : C, 67·6 ; H, 4·8 ; N, 4·7. $C_{16}H_{13}O_3NS$ requires C, 67·8 ; H, 4·6 ; N, 4·9%). 6 : 7-*Benzthionaphthenquinone*-2-p-*hydroxyanil*, from the thioindoxyl (I*f*) (30 g.) and *p*-nitrosophenol (22 g.), formed brownish-red crystals (glycol monoethyl ether), m. p. 280—282° (decomp.) (Found : C, 70·7 ; H, 3·9 ; N, 4·7. $C_{17}H_{11}O_2NS$ requires C, 70·8 ; H, 3·6 ; N, 4·6%). The above three anils were converted into the corresponding quinones by hydrolysis with hot hydrochloric acid (15%) ; the crude quinones were dissolved in hot sodium carbonate solution, which was acidified after filtration to precipitate the pure material.

Oxindole was prepared by the cyclisation of α-chloroacetanilide in the presence of aluminium chloride, thio-oxindole in low yield by Marschalk's method (*loc. cit.*), isatin in good yield by the method described in D.R.-P. 229,815, isatin chloride by Baeyer's method (*Ber.*, 1879, **12**, 456; it remained unchanged for many months in a well-closed bottle), and acenaphthenone by Graebe's method (*Annalen*, 1896, **290**, 198).

Preparation of Dyes.—General conditions are given below; an excess (1·2 mols.) of the second reactant was used throughout to ensure the absence of the slightly soluble first reactant in the product.

(1) *Condensation of thionaphthenquinones with thioindoxyls.* A mixture of the quinone (1—2 g.), the thioindoxyl (1·2 mols.), glacial acetic acid (30 c.c.), and zinc chloride (*ca.* 0·2 g.) was refluxed for 2 hours. A shorter period would have sufficed in some cases; *e.g.*, 30 mins. for (III*e*) and (III*f*). The zinc chloride could sometimes be replaced by concentrated hydrochloric acid (2 drops), but longer boiling was then required. After cooling, the dye was collected and washed with alcohol and water. Yields, usually about 70%. For dyeing tests, unrecrystallised material was used, as it was much more readily dispersed than crystallised material. For analysis and *X*-ray examination, the dye was recrystallised from boiling nitrobenzene, washed with benzene and alcohol, and dried at 130°/1·2 mm.

(2) *Condensation of anils with thioindoxyls, indoxyl, oxindole, and acenaphthenone.* This was performed exactly as in (1), except that hydrochloric acid (1 drop) was used in place of zinc chloride [the latter combines with the *p*-dimethylamino-anils to give slightly soluble double salts (green iridescent needles) which do not undergo further reaction]. Yields, 75—95%.

(3) *Condensation of thionaphthenquinones with indoxyl and with oxindole.* That with indoxyl was carried out precisely as in (2) and proceeded readily; yields, almost quantitative. That with oxindole proceeded least readily of all, and was carried out in acetic anhydride with zinc chloride, the conditions being otherwise as in (1); yields about 70%.

(4) *Condensation of isatin with thioindoxyls.* This was carried out as in (2) and was generally complete after 30 mins.' boiling; yields, almost quantitative.

(5) *Condensation of isatin chloride with thioindoxyls.* This proceeded in acetic acid without the use of a condensing agent and was complete after 5 mins.' boiling; yields, almost quantitative.

(6) *Condensation of thionaphthenquinones with acenaphthenone.* This was attempted in acetic acid and in acetic anhydride, with and without zinc chloride. There was obtained only a low yield of brownish-black powder which could not be purified.

Preparation of Diacetyl-dihydro-derivatives (cf. Friedländer, *loc. cit.*).—Zinc dust was added to a boiling mixture of the dye (0·5 g.), acetic acid (5 c.c.), and acetic anhydride (5 c.c.). After 0·25—2 hours the colourless solution was filtered hot. The diacetyl-dihydro-compound (contaminated with zinc acetate), which crystallised on cooling, was dissolved in hot acetic anhydride and poured into water; the precipitated acetyl compound was recrystallised from acetic acid or acetic anhydride.

The acetyl derivatives of some of the simpler thioindirubins were moderately soluble in the above acetylating mixture, which therefore had to be slightly diluted with water to ensure initial separation of the derivative.

Alkali Fission of 2- *and* 3-*Thionaphthen-2'-indole-indigos* (XII *and* XIV) (cf. Friedländer, *loc. cit.*).—A mixture of the finely powdered dye (0·5 g.), 20% aqueous potassium hydroxide (7 c.c.), and alcohol (0·5 c.c.) was boiled until the solution became green and a grey precipitate of the aldehyde-potassium salt separated. After cooling, the precipitate was collected and dissolved in hot water; the solution was filtered and acidified with acetic acid. The precipitated aldehyde was recrystallised from dilute alcohol or converted into the phenylhydrazone.

Dyeing Tests.—A paste, prepared by grinding together the dye (0·1 g.), water (5 c.c.), and a few drops of Turkey red oil, was diluted with water (20 c.c.) and 10% aqueous solution hydroxide (2 c.c.), sodium hydrosulphite (0·5 g.) added, and the mixture heated in a stoppered flask at 70° until the dye had dissolved, a vatting assistant (*e.g.*, anthraquinone) being added if necessary. The vat was diluted with water to 200 c.c., 10% sodium hydroxide solution (4 c.c.) and sodium hydrosulphite (1 g.) added, and then a standard piece of the cotton fabric (2 g.). After the mixture had been kept at 70° for 30 minutes, the fabric was removed, wrung out, and suspended in the air for 5 minutes. It was then boiled for 30 minutes with 1% soap solution, washed thoroughly, dried, and ironed.

In some cases, a pair of compounds, proved by other means to be identical, gave slightly different tints on dyeing: this was probably due to faint traces of impurities in the quinone condensation products.

The thioindirubins often gave difficulty in dyeing (p. 407).

Tables II—VIII give the detailed evidence upon which the final conclusions stated in Table I have been based.

TABLE II.

Condensation of (A) *Thionaphthenquinone* (III), *and* (B) *its Anil, with the Thioindoxyls.*

Thioindoxyl.		*Diacetyl-dihydro-derivatives and m. p.*	*X-Ray data.*	*Dyeing Tests.*	*Condensation.*
Thioindoxyl (I)	A	Colourless needles, 148—149°		Very weak red	β
	B	Colourless needles, 248°		Bluish-red	
6-Chloro-4-methyl- (I*b*)	A	White plates, 144—145°		Pinkish-red	β
	B	White needles, 182—183°		Bright-red	
6-Ethoxy- (I*d*)	A	Colourless crystals, 131—133°		Weak orange	β
	B	Pink leaflets, 162—165°		Bright orange-red	
4 : 5-Benz- (I*e*)	A	Pale brown plates, 162—163°	Non-id.	Very weak brown	β
	B	Pale brown needles, 214—217°	,,	Bordeaux-red	
6 : 7-Benz- (I*f*)	A	Pale brown plates, 178—179°			β
	B	Colourless needles, 254—256°			
5 : 6-Benz- (I*g*)	A	Not formed (p. 407)	Non-id.	Very pale blue	β
	B	Pale green plates, 254—256°	,,	Blue	

6-*Chloro*-4-*methylthioindirubin* (Found: S, 18·9. $C_{17}H_9O_2ClS_2$ requires S, 18·7%); *diacetyl-dihydro*-derivative (Found: C, 59·0; H, 2·7. $C_{21}H_{15}O_4ClS_2$ requires C, 59·3; H, 2·6%); 6-*chloro*-4-*methylthioindigo* (Found: S, 18·9%) (U.S.P. 1,709,982); *diacetyl-dihydro*-derivative (Found: C, 59·0; H, 2·9%). 6-*Ethoxythioindirubin* (Found: S, 18·9. $C_{18}H_{12}O_3S_2$ requires S, 18·8%); *diacetyl-dihydro*-derivative (Found: C, 61·7; H, 4·4. $C_{22}H_{18}O_5S_2$ requires C, 62·0; H, 4·3%): 6-*ethoxythioindigo* (Found: S, 18·9%) (U.S.P. 1,709,982); *diacetyl-dihydro*-derivative (Found: C, 62·3; H, 4·5%). 4 : 5-*Benzthioindirubin* (Found: S, 18·3. $C_{20}H_{10}O_2S_2$ requires S, 18·6%); *diacetyl-dihydro*-derivative (Found: C, 66·5; H, 3·7. $C_{24}H_{16}O_4S_2$ requires C, 66·7; H, 3·7%): 4 : 5-*benzthioindigo* (Found: S, 18·7%) (B.P. 211,120, 233,831; D.R.-P. 466,535); *diacetyl-dihydro*-derivative (Found: C, 66·6; H, 3·9%). 5 : 6-*Benzthioindirubin* (Found: S, 18·3%); *diacetyl-dihydro*-derivative (Found: C, 66·6; H, 3·9%); 5 : 6-*benzthioindigo* (Found: S, 18·8%) (B.P. 219,280, 233,831; D.R.-P. 450,852); *diacetyl-dihydro*-derivative (Found: C, 66·4; H, 3·8%). 6 : 7-*Benzthioindirubin* (Found: S, 18·9%); *diacetyl-dihydro*-derivative (Found: C, 66·4; H, 4·0%). 6 : 7-*Benzthioindigo* (Found: S, 18·6%) (D.R.-P. 466,535); *diacetyl-dihydro*-derivative (Found: C, 66·7; H, 3·9%).

TABLE III.

Condensation of (A) 6-*Chloro*-4-*methylthionaphthenquinone* (III*b*), *and* (B) *its Anil, with the Thioindoxyls.*

Thioindoxyl		*Diacetyl-dihydro-derivatives and m. p.*	X-*Ray data.*	*Dyeing Tests.*	*Condensation.*
Thioindoxyl (I)	A	White needles, 183—184°			*a*
	B	,, ,,			
6-Chloro-4-methyl- (I*b*)	A	Colourless needles, 290—292°			*a*
	B	,, ,,			
6-Ethoxy- (I*d*)	A	Pale pink plates, 178—181°	Id.	Pale red	*a*
	B	,, ,, ,, 181—182°	,,	Much deeper red	
4 : 5-Benz- (I*e*)	A	Pale brown needles, 196—198° (decomp.)		Bordeaux-red	*a*
	B	,, ,, ,, 197—199° (decomp.)		,, ,,	
6 : 7-Benz- (I*f*)	A	Pale brown needles, 252—253° (decomp.)			*a*
	B	,, ,, ,,			
5 : 6-Benz- (I*g*)	A	Pale greenish-yellow needles, 261—263°			*a*
	B	,, ,, ,,			

5 : 6′-*Dichloro*-4 : 4′-*dimethylthioindigo* (Found : S, 16·2. $C_{18}H_{10}O_2Cl_2S_2$ requires S, 16·3%) (D.R.-P. 241,910, 239,094); *diacetyl-dihydro*-derivative (Found : C, 54·8; H, 3·7. $C_{22}H_{16}O_4Cl_2S_2$ requires C, 55·1; H, 3·35%). 6′-*Chloro*-6-*ethoxy*-4′-*methylthioindigo* (Found : S, 16·7. $C_{19}H_{13}O_3ClS_2$ requires S, 16·4%) (B.P. 222,094, 232,230; U.S.P. 1,568,458); *diacetyl-dihydro*-derivative (Found : C, 57·4; H, 4·1. $C_{23}H_{19}O_5ClS_2$ requires C, 58·0; H, 4·0%). 6′-*Chloro*-4′-*methyl*-4 : 5-*benzthioindigo* (Found : S, 16·1. $C_{21}H_{11}O_2ClS_2$ requires S, 16·2%); *diacetyl-dihydro*-derivative (Found : C, 62·1; H, 3·6. $C_{25}H_{17}O_4ClS_2$ requires C, 62·5; H, 3·5%). 6′-*Chloro*-4′-*methyl*-6 : 7-*benzthioindigo* (Found : S, 16·5%); *diacetyl-dihydro*-derivative (Found : C, 62·1; H, 3·9%). 6′-*Chloro*-4′-*methyl*-5 : 6-*benzthioindigo* (Found : S, 16·6%); *diacetyl-dihydro*-derivative (Found : C, 62·4; H, 3·7%).

TABLE IV.

Condensation of (A) 5-*Chloro*-7-*methylthionaphthenquinone* (III*c*), *and* (B) *its Anil, with the Thioindoxyls.*

Thioindoxyl.		*Diacetyl-dihydro-derivatives and m. p.*	X-*Ray data.*	*Dyeing Tests.*	*Condensation.*
Thioindoxyl (I)	A	Colourless needles, 213—215°			*a*
	B	,, ,,			
5-Chloro-7-methyl- (I*c*)	A	Colourless needles, 308—310°			*a*
	B	,, ,,			
6-Ethoxy- (I*d*)	A	Colourless needles, 214—216°			*a*
	B	,, ,,			
4 : 5-Benz- (I*e*)	A	Pale brown needles, 269—272°			*a*
	B	,, ,, ,, 270—272°			
6 : 7-Benz- (I*f*)	A	Colourless needles, 167—169°	Non-id.	Pale brownish-violet	*β*
	B	,, ,, 235—238°	,,	Deep mauve	
5 : 6-Benz- (I*g*)	A	Pale greenish-yellow needles, 258—260°		Blue	*a*
	B	,, ,, ,,		Blue	

5-*Chloro*-7-*methylthioindigo* (Found : S, 19·0. $C_{17}H_9O_2ClS_2$ requires S, 18·7%); *diacetyl-dihydro*-derivative (Found : C, 59·3; H, 2·8. $C_{21}H_{15}O_4ClS_2$ requires C, 59·3; H, 2·6%). 5 : 5′-*Dichloro*-7 : 7′-*dimethylthioindigo* (Found : S, 16·5. $C_{18}H_{10}O_2Cl_2S_2$ requires S, 16·3%) (D.R.-P. 241,910, 243,087); *diacetyl-dihydro*-derivative (Found : C, 55·2; H, 3·6. $C_{22}H_{16}O_4Cl_2S_2$ requires C, 55·1; H, 3·35%). 5-*Chloro*-6′-*ethoxy*-7-*methylthioindigo* (Found : S, 16·6. $C_{19}H_{13}O_3ClS_2$ requires S, 16·4%); *diacetyl-dihydro*-derivative (Found : C, 57·5; H, 4·1. $C_{23}H_{19}O_5ClS_2$ requires C, 58·0; H, 4·0%). 5′-*Chloro*-7′-*methyl*-4 : 5-*benzthioindigo* (Found : S, 16·0. $C_{21}H_{11}O_2ClS_2$ requires S, 16·2%); *diacetyl-dihydro*-derivative (Found : C, 62·2; H, 3·7. $C_{25}H_{17}O_4ClS_2$ requires C, 62·5; H, 3·5%). 5′-*Chloro*-7′-*methyl*-6 : 7-*benzthioindirubin* (Found : S, 16·5%); *diacetyl-dihydro*-derivative (Found : C, 62·2; H, 3·7%); 5′-*chloro*-7′-*methyl*-6 : 7-*benzthioindigo* (Found : S, 16·0%); *diacetyl-dihydro*-derivative (Found : C, 62·4; H, 3·7%). 5′-*Chloro*-7′-*methyl*-5 : 6-*benzthioindigo* (Found : S, 16·0%) (B.P. 251,293); *diacetyl-dihydro*-derivative (Found : C, 62·3; H, 3·3%).

TABLE V.

Condensation of (A) 6-*Ethoxythionaphthenquinone* (III*d*), *and* (B) *its Anil, with the Thioindoxyls.*

Thioindoxyl.		*Diacetyl-dihydro-derivatives and m. p.*	X-*Ray data.*	*Dyeing Tests.*	*Condensation.*
6-Chloro-4-methyl- (I*b*)	A	Pinkish plates, 138—140°	Non-id.	Very deep red	*β*
	B	Pale pink needles, 181—182°	,,	,, ,, ,,	
5-Chloro-7-methyl- (I*c*)	A	Pale brown plates, 148—149°			*β*
	B	Colourless needles, 213—215°			
6-Ethoxy- (I*d*)	A	Pale pink needles, 144—146°		Pale orange	*β*
	B	Pale brown crystals, 230—232°		Intense orange	
6 : 7-Benz- (I*f*)	A	Brown plates, 166—169°		Very pale mauve	*β*
	B	Pale pink needles, 205—208°		Mauve	
5 : 6-Benz- (I*g*)	A	Not formed			*β*
	B	Pale yellow plates, 224—225° (decomp.)			

6-*Chloro*-6′-*ethoxy*-4-*methylthioindirubin* (Found : S, 16·7. $C_{19}H_{13}O_3ClS_2$ requires S, 16·4%); *diacetyl-dihydro*-derivative (Found : C, 57·6; H, 4·1. $C_{23}H_{19}O_5ClS_2$ requires C, 58·0; H, 4·0%). 5-*Chloro*-6′-*ethoxy*-7-*methylthioindirubin* (Found : S, 16·6%); *diacetyl-dihydro*-derivative (Found : C, 57·5; H, 4·2%). 6 : 6′-*Diethoxythioindirubin* (Found : S, 16·9. $C_{20}H_{16}O_4S_2$ requires S, 16·6%); *diacetyl-dihydro*-derivative (Found : C, 61·0; H, 4·9. $C_{24}H_{22}O_6S_2$ requires C, 61·3; H, 4·7%) : 6 : 6′-*diethoxythioindigo* (Found : S, 16·6%) (D.R.-P. 237,680, 239,089—91); *diacetyl-dihydro*-derivative (Found : C, 61·1; H, 4·8%). 6′-*Ethoxy*-6 : 7-*benzthioindirubin* (Found : S, 16·1. $C_{22}H_{14}O_3S_2$ requires S, 16·4%); *diacetyl-dihydro*-derivative (Found : C, 67·4; H, 3·8. $C_{26}H_{20}O_5S_2$ requires C, 67·7; H, 3·6%) : 6′-*ethoxy*-6 : 7-*benzthio*-

indigo (Found : S, 16·7%) ; *diacetyl-dihydro*-derivative (Found : C, 67·3 ; H, 3·7%). 6′-*Ethoxy*-5 : 6-*benzthioindirubin* (Found : S, 16·6%) ; *diacetyl-dihydro*-derivative (Found : C, 67·7 ; H, 3·7%) : 6′-*ethoxy*-5 : 6-*benzthioindigo* (Found : S, 16·1%) ; *diacetyl-dihydro*-derivative (Found : C, 67·3 ; H, 3·7%).

TABLE VI.

Condensation of (A) 4 : 5-*Benzthionaphthenquinone* (III*e*), *and* (B) *its Anil, with the Thioindoxyls.*

Thioindoxyl.		*Diacetyl-dihydro-derivatives and m. p.*	*X-Ray data.*	*Dyeing Tests.*	*Condensation.*
Thioindoxyl (I)	A	Pale brown needles, 214—217°	Id.	Bordeaux-red	*a*
	B	,, ,, ,,	,,	,, ,,	
6-Chloro-4-methyl- (I*b*)	A	Pale brown needles, 196—198° (decomp.)			*a*
	B	,, ,, ,,			
5-Chloro-7-methyl- (I*c*)	A	Yellow-brown needles, 274—276°			*a*
	B	,, ,,			
6-Ethoxy- (I*d*)	A	Yellowish plates, 221—224°			*a*
	B	,, ,, 223—225°			
4 : 5-Benz- (I*e*)	A	Pale brown needles, >315°	Id.	Brown	*a*
	B	,, ,, ,,	,,		
6 : 7-Benz- (I*f*)	A	Pale brown needles, 255—257°		Pale brownish-violet	*a*
	B	,, ,, ,, 254—257°		Brownish-violet	
5 : 6-Benz- (I*g*)	A	Greenish-yellow plates, 263—265°			*a*
	B	,, ,,			

6′-*Ethoxy*-4 : 5-*benzthioindigo* (Found : S, 16·7. $C_{22}H_{14}O_3S_2$ requires S, 16·4%) ; *diacetyl-dihydro*-derivative (Found : C, 67·3 ; H, 3·9. $C_{26}H_{20}O_5S_2$ requires C, 67·7 ; H, 3·6%). 4 : 5 : 4′ : 5′-*Dibenzthioindigo* (Found : S, 16·1. $C_{24}H_{12}O_2S_2$ requires S, 16·2%) (D.R.-P. 239,094) ; *diacetyl-dihydro*-derivative (Found : C, 69·5 ; H, 4·1. $C_{28}H_{18}O_4S_2$ requires C, 69·7 ; H, 3·7%). 4 : 5 : 6′ : 7′-*Dibenzthioindigo* (Found : S, 16·4%) ; *diacetyl-dihydro*-derivative (Found : C, 69·5 ; H, 4·2%). 4 : 5 : 5′ : 6-*Dibenzthioindigo* (Found : S, 16·5%) ; *diacetyl-dihydro*-derivative (Found : C, 69·7 ; H, 3·6%).

TABLE VII.

Condensation of (A) 6 : 7-*Benzthionaphthenquinone* (III*f*), *and* (B) *its Anil, with the Thioindoxyls.*

Thioindoxyl.		*Diacetyl-dihydro-derivatives and m. p.*	*X-Ray data.*	*Dyeing Tests.*	*Condensation.*
Thioindoxyl (I)	A	Colourless needles, 254—256°			*a*
	B	,, ,,			
5-Chloro-7-methyl- (I*c*)	A	Colourless needles, 235—238°			*a*
	B	,, ,,			
6-Ethoxy- (I*d*)	A	Pale pink plates, 162—165°		Dull brown-red	*β*
	B	Pale pink needles, 205—208°		,, ,, ,,	
4 : 5-Benz- (I*e*)	A	Pale brown plates, 227—230° *		Dark brown	*β*
	B	Pale brown needles, 255—257° *		,, ,,	
6 : 7-Benz- (I*f*)	A	Colourless plates, >315°	Id.	Brown	*a*
	B	,, ,,	,,	,,	
5 : 6-Benz (I*g*)	A	Pale green plates, 251—253°	Id.		*a*
	B	,, ,, ,, 252—253°	,,		

* Mixed m. p. 215—223°.

Ethoxy-6′ : 7′-*benzthioindirubin* (Found : S, 16·7. $C_{22}H_{14}O_3S_2$ requires S, 16·4%) ; *diacetyl-dihydro*-derivative (Found : C, 67·5 ; H, 3·6. $C_{26}H_{20}O_5S_2$ requires C, 67·7 ; H, 3·6%). 4 : 5 : 6′ : 7′-*Dibenzthioindirubin* (Found : S, 16·5. $C_{24}H_{12}O_2S_2$ requires S, 16·2%) ; *diacetyl-dihydro*-derivative (Found : C, 69·5 ; H, 3·7. $C_{28}H_{18}O_4S_2$ requires C, 69·7 ; H, 3·7%). 6 : 7 : 6′ : 7′-*Dibenzthioindigo* (Found : S, 16·4%) (D.R.-P. 239,093) ; *diacetyl-dihydro*-derivative (Found : C, 69·6 ; H, 3·9%). 5 : 6 : 6′ : 7′-*Dibenzthioindigo* (Found : S, 16·5%) (D.R.-P. 519,747) ; *diacetyl-dihydro*-derivative (Found : C, 69·3 ; H, 3·9%).

TABLE VIII.

Condensation of (A) 5 : 6-*Benzthionaphthenquinone* (III*g*), *and* (B) *its Anil, with the Thioindoxyls.*

Thioindoxyl.		*Diacetyl-dihydro-derivatives and m. p.*	*X-Ray data.*	*Dyeing Tests.*	*Condensation.*
Thioindoxyl (I)	A	Not formed (p. 407)			*β*
	B	Pale green plates, 254—256°			
5-Chloro-7-methyl- (I*c*)	A	Not formed			*β*
	B	Pale greenish-yellow needles, 258—260°			
6-Ethoxy- (I*d*)	A	Not formed			*β*
	B	Pale yellow plates, 224—225° (decomp.)			
4 : 5-Benz- (I*e*)	A	Not formed		Pale fawn	*β*
	B	Greenish-yellow needles, 263—265°		Mauve	
6 : 7-Benz- (I*f*)	A	Not formed	Non-id.	Very pale mauve	*β*
	B	Greenish-brown plates, 251—253°	,,	Deep violet	
5 : 6-Benz- (I*g*)	A	Not formed		Pale bluish-green	*β*
	B	Pale green needles, 297—300° (decomp.)		Dark greenish-blue	

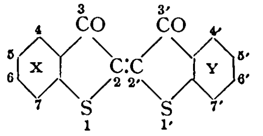
5-*Chloro*-7-*methyl*-5′ : 6′-*benzthioindirubin* (Found : S, 16·3. $C_{21}H_{11}O_2ClS_2$ requires S, 16·2%). 6-*Ethoxy*-5′ : 6′-*benzthioindirubin* (Found : S, 16·6%). 4 : 5 : 5′ : 6′-*Dibenzthioindirubin* (Found : S, 16·0%). 6 : 7 : 5′ : 6′-*Dibenzthioindirubin* (Found : S, 16·5%). 5 : 6 : 5′ : 6′-*Dibenzthioindirubin* (Found : S, 16·5%) ; 5 : 6 : 5′ : 6′-*dibenzthioindigo* (Found : S, 16·5%) (B.P. 219,280) ; *diacetyl-dihydro*-derivative (Found : C, 70·0 ; H, 3·9%).

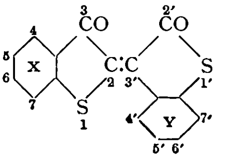
Each table gives the reactions of one thioquinone (A) and its α-anil (B) with each of the thioindoxyls studied. The third column gives the m. p.'s of the diacetyl-dihydro-derivatives : when these were identical for a pair of derivatives, their chemical identity was always confirmed by mixed m. p. determinations. The *X*-ray data in the fourth column are given as Id. = identical, and Non-id. = non-identical. The last column (Type of Condensation) indicates the particular carbonyl group of the thioquinone which has reacted : the reference compound obtained from the α-anil (B) is always the α-condensation product.

The names and analytical data of all new compounds are given below each table in the order in which they appear. In all cases, unless otherwise stated, nitrobenzene has been used as a recrystallising solvent for the dye and acetic acid for the diacetyl-dihydro-derivatives.

The thioindigos and thioindirubins are named according to (XXXIV) and (XXXV) respectively.

(XXXIV.)





(XXXV.)

Condensation Products of Indoxyl and the Thionaphthenquinones.—In this series, the direct comparison in properties of (A) the compounds obtained by the condensation of indoxyl with the quinones, and (B) the reference compounds prepared by the condensation of isatin chloride with the required thioindoxyl, cannot be conveniently tabulated, as the compounds were identified by their alkali fission products, the aldehydes so obtained being identified sometimes as free aldehydes and sometimes (when this proved difficult) as their phenylhydrazones. The two series (A) and (B) differed throughout, the (B) series being necessarily 2-thionaphthen-2′-indole-indigos (XII) giving substituted thioindoxyl-2-aldehydes (XVI) (p. 407), and the (A) series being therefore 3-thionaphthen-2′-indole-indigos (XIV) giving substituted thio-oxindole-3-aldehydes (XV). The compounds and their derivatives in each series are therefore given separately. Since the difference between the two series was manifest, standard dyeing tests were not made, and the colour of the crystalline dye is therefore recorded. General dyeing tests showed, however, that both series (A) and (B) formed good dyes. All the dyes in (A) and (B) were recrystallised from nitrobenzene, and the aldehydes and their phenylhydrazones from dilute alcohol.

(A) Indoxyl condensed with : (i) the quinone (III) gives the indigo (XIV), which on alkali fission gives the aldehyde (XV) : this was shown by Friedländer (*loc. cit.*) and was therefore not repeated.

(ii) the quinone (III*b*) gave 3-(6-*chloro*-4-*methylthionaphthen*)-2′-*indole-indigo*, reddish-violet plates (Found : S, 9·9. $C_{17}H_{10}O_2NClS$ requires S, 9·7%), which gave 6-*chloro*-4-*methylthio-oxindole*-3-*aldehydephenylhydrazone*, m. p. 167—169° (Found : C, 61·1 ; H, 4·4 ; N, 8·7. $C_{16}H_{13}ON_2ClS$ requires C, 60·8 ; H, 4·1 ; N, 8·85%).

(iii) the quinone (III*c*) gave the corresponding 3-(5-*chloro*-7-*methyl*) derivative, violet plates (Found : S, 10·0%), which gave the 5-*chloro*-7-*methyl-aldehyde*, m. p. 116—118° (Found : C, 52·6 ; H, 3·5. $C_{10}H_7O_2ClS$ requires C, 53·0 ; H, 3·1%), *phenylhydrazone*, m. p. 194—196° (Found : C, 60·4 ; H, 4·2 ; N, 8·9%).

(iv) the quinone (III*d*) gave the 3-(6-*ethoxy*)-derivative, reddish-violet plates (Found : S, 10·2. $C_{18}H_{13}O_3NS$ requires S, 9·9%), which gave the 6-*ethoxy-aldehyde*, m. p. 152—154° (Found : C, 59·1 ; H, 4·6. $C_{11}H_{10}O_3S$ requires C, 59·5 ; H, 4·5%).

(v) the quinone (III*e*) gave the 3-(4 : 5-*benz*)-derivative, dark blue plates (Found : S, 9·4. $C_{20}H_{11}O_2NS$ requires S, 9·7%) (E.P. 189,782), which gave the 4 : 5-*benz-aldehyde*, m. p. 144—145° (Found : C, 68·6 ; H, 3·5. $C_{13}H_8O_2S$ requires C, 68·4 ; H, 3·5%).

(vi) the quinone (III*f*) gave the 3-(6 : 7-*benz*)-derivative, dark blue-violet plates (Found : S, 10·0%), which gave the 6 : 7-benz-aldehyde, identified as the *phenylhydrazone*, m. p. 220—222° (Found : C, 71·4 ; H, 4·7. $C_{19}H_{14}ON_2S$ requires C, 71·7 ; H, 4·4%).

(vii) the quinone (III*g*) gave the 3-(5 : 6-*benz*)-derivative, dark blue-violet plates (Found : S, 10·1%), which gave the 5 : 6-*benz-aldehyde*, m. p. 145—146° (Found : C, 68·9 ; H, 3·7%).

(B) Isatin chloride condensed with : (i) thioindoxyl (I) gives the indigo (XII), which on alkali splitting gives the aldehyde (XVI) : this was also shown by Friedländer and was not repeated.

(ii) the thioindoxyl (I*b*) gave 2-(6-*chloro*-4-*methylthionaphthen*)-2′-*indole-indigo*, violet crystals (Found : S, 10·1%), which gave 6-*chloro*-4-*methylthioindoxyl*-2-*aldehydephenylhydrazone*, m. p. 153—154° (Found : C, 60·6 ; H, 4·3%).

(iii) the thioindoxyl (I*c*) gave the corresponding 2-(5-*chloro*-7-*methyl*) derivative, deep blue plates (Found : S, 10·0%).

(iv) the thioindoxyl (I*d*) gave the 2-(6-*ethoxy*)-derivative, reddish-violet plates (Found : S, 10·2%).

(v) the thioindoxyl (I*e*) gave the 2-(4 : 5-*benz*)-derivative, reddish-violet plates (Found : S, 9·4%) (B.P. 233,831), which gave the 4 : 5-*benz-aldehyde*, m. p. 131—132° (Found : C, 68·2 ; H, 3·5%).

(vi) the thioindoxyl (I*f*) gave the 2-(6 : 7-*benz*)-derivative, deep blue plates (Found : S, 10·0%) (E.P. 233,831), which gave the 6 : 7-benz-aldehyde, identified as the *phenylhydrazone*, m. p. 197—200° (Found : C, 71·9 ; H, 4·6%).

(vii) the thioindoxyl (I*g*) gave the 2-(5 : 6-*benz*)-derivative, deep blue-violet plates (Found : S, 10·1%) (D.R.-P. 490,599 ; U.S.P. 1,709,982), which gave the 5 : 6-*benz-aldehyde*, m. p. 137—139° (Found : C, 68·1 ; H, 3·6%).

All attempts to prepare aldehydes by the alkali-splitting of the dyes in B (iii) and B (iv) above were unsuccessful, only highly-coloured alkali-soluble products being obtained.

Condensation Products of Oxindole and the Thionaphthenquinones.—In this series, (A) the compounds produced from the condensation of oxindole with the quinones, and (B) the reference compounds obtained either by the condensation of isatin with the thioindoxyls or by oxindole with the anils, were found throughout to be identical by *X*-ray investigation. Alkali splitting of the product (type XIII), to furnish the oxindole-3-aldehyde (XVII) (p. 407) was rarely used because of its difficulty. All the compounds produced in this series are therefore 2-thionaphthen-3′-indole-indigos : in the following list, the first analytical figure given refers to the product obtained in (A) and the second to that in (B).

(i) 2-Thionaphthen-3′-indole-indigo, red needles (D.R.-P. 182,260, 241,327).

(ii) 2-(6-*Chloro*-4-*methylthionaphthen*)-3′-*indole-indigo*, red needles (Found : S, 9·3. $C_{17}H_{10}O_2NClS$ requires S, 9·7%).

(iii) the 2-(5-*chloro*-7-*methyl*) derivative, reddish needles (Found : S, 10·0, 10·1%).

(iv) the 2-(6-*ethoxy*)-derivative, red needles (Found : S, 9·6, 10·1. $C_{18}H_{13}O_3NS$ requires S, 9·9%).

(v) the 2-(4 : 5-*benz*)-derivative, dark brown needles (Found : S, 10·1, 9·7. $C_{20}H_{11}O_2NS$ requires S, 9·7%) (B.P. 198,415).

(vi) the 2-(6 : 7-benz)-derivative, dark brown needles (Found : S, 9·3, 9·8%) (Dutta, *Ber.*, 1933, **66**, 1230).

(vii) the 2-(5 : 6-benz)-derivative, violet-brown plates (Found : S, 10·1, 9·9%) (Dutta, *Ber.*, 1934, **67**, 1324).

2-*Acetamido*-1-*naphthylthioglycollic Acid* (XXX).—Acetic anhydride (40 c.c. ; 2 mols.) was added dropwise with stirring to a solution of the sodium salt of the acid (XXIX) (100 g., 85% pure) in water (300 c.c.). Stirring was continued for 1 hour, during which much grey precipitate formed, and then 10% sodium hydroxide solution (350 c.c.) was slowly added, and the solution filtered from traces of the amino-acid lactam. The filtrate on acidification gave the *acid* (XXX), long colourless needles (alcohol), m. p. 185° (Found: C, 61·4; H, 4·8; N, 5·2. $C_{14}H_{13}O_3NS$ requires C, 61·1; H, 4·7; N, 5·1%). The addition of the sodium hydroxide in this preparation is essential, otherwise the final product (XXX) is heavily contaminated with the acid-lactam.

Attempted cyclisation. The directions given in the D.R.-P. 414,084 (addition of the acid to chlorosulphonic acid in the absence of solvent) gave only the thioindigo and sulphonated products. The same result was obtained with chlorosulphonic acid (1—4 mols.) in tetrachloroethane as solvent and it seems that, although the required thioindoxyl is formed, it is impossible to prevent oxidation and sulphonation occurring.

2-*Chloro*-1-*naphthylthioglycollic Acid*.—A solution of the crude sodium salt of the amino-acid (XXIX) (100 g.) and sodium nitrite (25 g.) in water (300 c.c.) was run into a mixture of ice (300 g.) and concentrated hydrochloric acid (200 c.c.), and this solution in turn added to a solution of cuprous chloride (50 g.) in concentrated hydrochloric acid (200 c.c.) at 70°; a brown oil separated. The temperature was then increased to 90° for 1 hour, and the mixture finally cooled, the brown oil solidifying. The aqueous solution was decanted from the sticky brown solid, which was dissolved in hot 5% sodium hydroxide solution. The latter was filtered and cooled, and the sodium salt of the chloro-acid salted out, collected, and partly purified by recrystallisation from 15% brine. The *chloro-acid* was precipitated by the addition of hydrochloric acid to a chilled aqueous solution of this sodium salt, and obtained as a sticky product which solidified. It was recrystallised thrice from dilute alcohol (charcoal) and once from benzene–*cyclo*hexane, forming colourless crystals (19 g.), m. p. 95—97° (Found: C, 57·2; H, 3·7; Cl, 13·8. $C_{12}H_9O_2ClS$ requires C, 57·2; H, 3·5; Cl, 14·1%).

Attempted cyclisation. Chlorosulphonic acid (9 g.; 1·5 mols.) was added dropwise to a well-stirred suspension of the acid (13 g.) in tetrachloroethane (50 c.c.) at 0—5°. After 2 hours, water was added, and the tetrachloroethane removed in steam. The sticky brown residue was almost completely soluble in hot sodium carbonate solution and was unaffected by potassium ferricyanide. It was therefore the unchanged acid. The same result was obtained when the acid (10 g.) was added in small portions to chlorosulphonic acid (20 g.) with stirring at 0°, though in this case a small amount of the blue thioindigo was also obtained. An attempt at cyclisising the acid chloride (XXXIII) with aluminium chloride, as in the preparation of 5-chloro-7-methylthioindoxyl, was equally unsuccessful, the only product obtained being the impure thioindigo.

In view of the considerable value of diacetyl-dihydro-derivatives for the rapid identification of the parent thioindigos and thioindirubins, the m. p.'s of the derivatives described above are collected in Table IX. The benzene rings in each molecule are differentiated as X and Y, according to formulæ (XXXIV) and (XXXV). In the columns headed "Thioindirubin derivative," a blank space indicates that the parent thioindirubin has not been obtained in this investigation, and "n.f." indicates that the thioindirubin has been obtained but does not form a diacetyl-dihydro-derivative.

TABLE IX.

M. p.'s of Diacetyl-dihydro-derivatives of Thioindigos and Thioindirubins.

Substitution.		Thioindigo derivative.	Thioindirubin derivative.	Substitution.		Thioindigo derivative.	Thioindirubin derivative.
X.	Y.			X.	Y.		
—	—	248°	148—149°	5-Cl-7-Me	4 : 5-Benz	274—276°	
6-Cl-4-Me	—	183—184	144—145	,,	5 : 6-Benz	258—260	n.f.
5-Cl-7-Me	—	213—215		6-OEt	6-OEt	230—232	144—146°
6-OEt	—	162—165	131—133	,,	4 : 5-Benz	223—225	
4 : 5-Benz	—	214—217	162—163	,,	5 : 6-Benz	224—225	n.f.
5 : 6-Benz	—	254—256	n.f.	,,	6 : 7-Benz	205—208	162—165
6 : 7-Benz	—	254—256	178—179	6 : 7-Benz	5-Cl-7-Me	235—238	167—169
6-Cl-4-Me	6-Cl-4-Me	290—292		,,	6-OEt	205—208	166—169
5-Cl-7-Me	5-Cl-7-Me	308—310		4 : 5-Benz	4 : 5-Benz	>315	
6-Cl-4-Me	6-OEt	181—182	138—140	,,	5 : 6-Benz	263—265	n.f.
,,	4 : 5-Benz	197—199		,,	6 : 7-Benz	255—257	227—230
,,	5 : 6-Benz	261—263		5 : 6-Benz	5 : 6-Benz	297—300	n.f.
,,	6 : 7-Benz	252—253		6 : 7-Benz	6 : 7-Benz	>315	
5-Cl-7-Me	6-OEt	214—216	148—149	,,	5 : 6-Benz	252—253	n.f.

This Table shows that symmetric substitution in the thioindigo derivatives is associated with high m. p.; *e.g.*, the 4 : 5 : 4′ : 5′-dibenz-derivative has a higher m. p. than the isomeric unsymmetric 4 : 5 : 5′ : 6′- and 4 : 5 : 6′ : 7′-derivatives.

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