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SYNTHESIS OF SUBSTITUTED LINEAR FURANO[2,3-g][1]BENZOPYRONES AND [3,2-b]THIANAPHTHENOPYRONES

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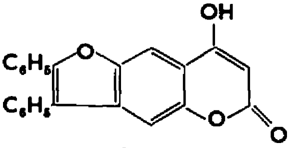
Abstract—The synthesis of the linear furanopyrones: 2,3-diphenyl-8-hydroxy-6H-furano[2,3-g][1]-benzopyran-6-one (I) and 2,3-diphenyl-6-methyl-8H-furano[2,3-g][1]benzopyran-8-one (II) is described.

Hetero-oxygen-ring opening in 4-hydroxy-2-oxo-2H-pyrano[3,2-b]thianaphthene (IVa) has been accomplished by the action of aromatic amines.

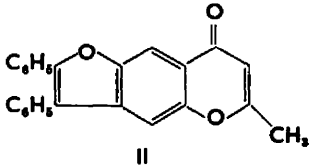
Treatment of the new 3-acyl-4-hydroxy-2-oxo-2H-pyrano[3,2-b]thianaphthenes (IVb–d) with amines yielded the corresponding amino or imino compounds (VIIa–f).

Synthesis of the new 2-aryl-4-oxo-4H-pyrano[3,2-b]thianaphthenes (Xa–c) is described. The β-sulfides (XIa–k) have been obtained via the addition of the appropriate thiols to the chalcones (IXa–f). 2-Cinnamoyl-3-hydroxythianaphthene 1,1-dioxides (XIIa–b) form labile adducts with thiols.

Recently, Musajo and Rodighiero[1] have studied many furanocoumarins for their photodynamic activity and have shown that the linear furanocoumarin structure, e.g. psoralene, the simplest linear furanocoumarin, is more active than the isomeric angular furanocoumarin, e.g. angelicin. In the course of the present work, 2,3-diphenyl-8-hydroxy-6H-furano[2,3-g][1]benzopyran-6-one (I) and 2,3-diphenyl-6-methyl-8H-furano[2,3-g][1]benzopyran-8-one (II) have been synthesized in good yields.



I



II

The furanocoumarin with a skeleton of the type I is isomeric with 4-hydroxybergapten and 4-hydroxyisopimpinellin.

Compound I is now obtained by the action of ethyl carbonate on IIIe. Meanwhile, when IIIe undergoes a Claisen condensation with ethyl acetate, followed by cyclization of the IIIf formed, II is obtained (cf. Scheme A).

Under the Friedel-Crafts conditions, IIIe is obtained together with an isomeric product, believed to be 4-acetyl-5-hydroxy-2,3-diphenylbenzofuran.[2] The structure assigned to the latter isomer is not definite, and further investigation is in progress.

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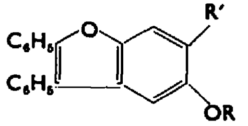
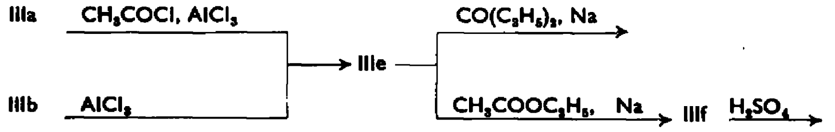
[1] L. Musajo and G. Rodighiero, *Experientia* **18**, 153 (1962).

[2] Cf. the formation of 5- and 7-acetyl-6-hydroxy derivatives upon the BF_3-catalysed acetylation of methyl 6-hydroxy-coumarilate [P. K. Ramachandran, A. T. Tefteller, G. O. Paulson, T. Cheng, C. T. Lin and W. J. Horton, *J. Org. Chem.* **28**, 398 (1963)].



III a, R=R'=H
b, $R=COCH_3$; R'=H
c, $R=COCH{=}CHC_6H_5$; R'=H
d, $R=CH_2CH{=}CH_2$; R'=H
e, R=H; $R'=COCH_3$
f, R=H; $R'=COCH_2COCH_3$
g, R=H; $R'=COCH{=}CHC_6H_5$
h, R=H; $R'=CH_2CH{=}CH_2$



Scheme A

The NMR spectra of I and II support the assigned linear structures; and favour the structure assigned to IIIe. In the spectrum of the linear isomer (I),[3] there are singlets at 7·92 ppm and 7·18 ppm corresponding to two isolated standing aromatic protons. The signal group at 7·4 ppm has the intensity 11 and belongs to 10 protons of the phenyl rings and one proton for the hydroxyl hydrogen of the enol group.

In the spectrum of the linear isomer (II), a singlet of an isolated standing aromatic proton appears at 8·24 ppm. The signal group at 7·4 ppm has the intensity 11 and corresponds to the protons of both the phenyl rings as well as to an aromatic proton on the chromone frame. The singlet at 6·14 ppm corresponds to a singly standing proton on an olefinic double bond, apparently in the γ-pyrone moiety. The singlet at 2·35 ppm corresponds to the 3 protons of a methyl group at the double bond.

The IR spectrum of III shows strong peaks characteristic of α,β-unsaturated-δ-lactones in the region of carbonyl absorption, and of an—OH group.[4,5]

The acidic property of I is similar to that of 4-hydroxycoumarin, 4-hydroxy-3-acetylcoumarin, 4-hydroxybergapten,[6] 4-hydroxyisopimpinellin,[6] 4-hydroxy- (IVa) and 4-hydroxy-3-acetyl-2-oxo-2H-pyrano[3,2-b]thianaphthene (IVb). This is not surprising, because the system present in these compounds is equivalent to a monovinylogue of a carboxylic acid, HO—CO—CR=CH—OH, in which the second hydroxyl group is separated from the carbonyl group by the vinyl system.[7]

It is of interest that substitution of the phenyl groups at the α- and β-positions in the furan ring of I and II effects its stabilization toward the action of mineral acids.[8]

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[3] Cf. K. D. Kaufman, J. F. W. Keana, R. C. Kelly, D. W. McBride, and G. Slomp, *J. Org. Chem.* 27, 2567 (1962).

[4] R. N. Jones and C. Sandorfy, *Technique of Organic Chemistry* (Edited by A. Weissberger) Vol. IX; p. 455; Interscience, New York (1956); P. Yates and G. H. Stout, *J. Amer. Chem. Soc.* 76, 5110 (1954); R. N. Jones, C. L. Angell, T. Ito and R. J. D. Smith, *Canad. J. Chem.* 37, 2007 (1959); H. H. Wasserman and R. C. Koch, *J. Org. Chem.* 27, 35 (1962).

[5] V. C. Farmer, *Spectrochim. Acta* 870 (1959).

[6] A. Schönberg, N. Badran and N. A. Starkowsky, *J. Amer. Chem. Soc.* 77, 5438 (1955).

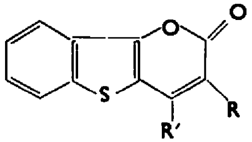
[7] G. H. Jones, J. B. D. Mackenzie, A. Robertson and W. B. Whalley, *J. Chem. Soc.* 562 (1949).

[8] R. T. Foster and A. Robertson, *J. Chem. Soc.* 921 (1939); R. C. Elderfield, *Heterocyclic Compounds* Vol. VII, pp. 31, 48, J. Wiley, New York (1961).

The reaction of IIIa with cinnamoyl chloride under the Friedel-Crafts conditions, as well as, the Fries rearrangement of IIIc with aluminium chloride has been investigated. Moreover, allylic rearrangement of IIId yields IIIh (cf. Experimental).

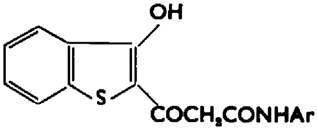
4-Hydroxy-2-oxo-2H-pyrano[3,2-b]thianaphthene (IVa) was first prepared by Smiles *et al.*, who also studied its condensation with formaldehyde, nitrous acid and aniline.[9a,b] Since this early work, the compound has received little attention. The discussion that follows compares the properties of this class of compound with the 4-hydroxycoumarins.

In initial experiments, 4-anilino-2-oxo-2H-pyrano[3,2-b]thianaphthene (IVl) was obtained by refluxing IVn with aniline in ethanol. When IVa is treated with *p*-toluidine under the experimental conditions reported by Smiles and Hart[9b] for the formation of IVl, compound IVm is produced.



IV a, R=H; R′=OH
b, $R=COCH_3$; R′=OH
c, $R=COC_2H_5$; R′=OH
d, $R=COC_3H_7$-n; R′=OH
e, $R=COC_3H_7$-iso; R′=OH
f, $R=COCH_2C_6H_5$; R′=OH
g, $R=NO_2$; R′=OH
h, $R=NHCOCH_3$; R′=OH
i, $R=N{=}NC_6H_5$; R′=OH
j, $R=N{=}NC_6H_4CH_3$-p; R′=OH
k, $R=N{=}NC_6H_4Cl$-p; R′=OH
l, R=H; $R'=NHC_6H_5$
m, R=H; $R'=NHC_6H_4CH_3$-p
n, R=H; R′=Cl
o, R=H; $R'=OCOC_6H_5$

The heterocyclic oxygen ring in IVa opens when it is heated with aniline or *p*-toluidine, in presence or absence of ethanol, to yield α-(3-hydroxy-2-thianaphthenoyl)-acetanilide (Va) and *p*-toluidide (Vb), respectively. Similarly, refluxing an ethanolic solution of the 4-benzoyloxy derivative, IVo with aniline, effects debenzoylation and formation of Va.



Va, $R=C_6H_5$
b, $R=C_6H_4CH_3$-p

The structure of Va has been elucidated as follows: (a) correct analytical results, (b) solubility in aqueous sodium hydroxide, (c) development of a green colour with ferric chloride, (d) the IR spectrum reveals the presence of —NH, —OH, $\rangle C{=}O$ and amide-C=O stretching vibrations; on the other hand, the IR spectrum of IVl absorbs

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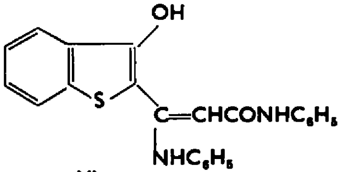
[9a] S. Smiles and E. W. McClelland, *J. Chem. Soc.* **119**, 1810 (1921), [b] S. Smiles and L. R. Hart, *Ibid.* **123**, 2907 (1923).

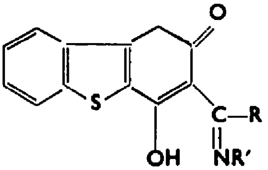
in the —NH and $>$C=O of α,β-unsaturated lactone stretching regions[4] and displays no —OH peak, (e) the ready formation of IVa upon boiling with acetic acid,[10] (f) Va on treatment with aniline at 180° is converted into IVa and a compound which is tentatively formulated as VI, (g) Va couples with benzenediazonium chloride to give a red azo-dye, which upon crystallization from acetic acid undergoes elimination of aniline and cyclization to IVi.



VI

The reaction of 3-acetyl-4-hydroxy-2-oxo-2H-pyrano[3,2-b]thianaphthene (IVb with amines is an extension of the reaction of β-diketones with amines.[11]

When IVb reacts with ammonium acetate, ethyl, n-butyl-, sec-butyl-, isobutylamine and *p*-toluidine, good yields of the corresponding amino or imino compounds, VIIa-f respectively are obtained. Similarly, IVc–d react with aniline to give VIIg–h, respectively. Compound IVb reacts with as-methylphenylhydrazine with the formation of VIIi.



VII a, $R=CH_3$; $R'=H$
b, $R=CH_3$; $R'=C_2H_5$
c, $R=CH_3$; $R'=C_4H_9$-n
d, $R=CH_3$; $R'=C_4H_9$-sec.
e, $R=CH_3$; $R'=C_4H_9$-iso
f, $R=CH_3$; $R'=C_6H_4CH_3$-p
g, $R=C_2H_5$; $R'=C_6H_5$
h, $R=C_3H_7$-n; $R'=C_6H_5$
i, $R=CH_3$; $R'=N(CH_3)C_6H_5$

The nitrogen function may enter IVb–d either at the 2-, 4- or 3α-positions. Substitution at the 2-position is considered least likely since aniline substitutes in the 4-position of IVa[9b] and in position 4 of 4-hydroxycoumarin.[12] Structures for the reaction products of 3-acyl-4-hydroxycoumarin with amines,[13] and with hydrazines[14] and of 2-acetyl-1,3-diketocyclohexane with aniline[15] support the above formulation (cf. VII).

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[10] Cf. the ready cyclization of acetoacetanilide oxime to 3-methylisoxazolin-5-one by the action of acetic acid [L. Knorr and B. Reuter, *Ber. Dtsch. Chem. Ges.* **27**, 1169 (1894)].

[11] N. H. Cromwell, *Chem. Revs.* **38**, 83 (1946).

[12] R. Anschütz, *Liebig's Ann.* **367**, 169 (p. 204) (1909).

[13] R. A. Kloss and C. Wiener, *J. Org. Chem.* **28**, 1671 (1963).

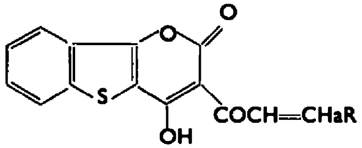
[14] A. Mustafa, O. H. Hishmat, A. A. Nawar and K. M. A. Khalil, unpublished work; N. S. Vul'fson and R. B. Zhurin, *Zh. Obshch. Khim.* **31**, 3381 (1961); *Chem. Abstr.* **57**, 4631 (1962).

[15] H. Smith, *J. Chem. Soc.* 803 (1953).

The compounds IVb–e, were prepared by the action of the corresponding carboxylic acid on IVa.[16] When IVa reacts with benzoyl chloride in pyridine,[17] the corresponding 4-benzoyloxy derivative, IVo, is obtained.

The IR spectrum of IVb shows a broad —OH absorption band which is similar to that in the 3-substituted 4-hydroxycoumarins, as well as a strong peak which is in good agreement with the spectra of α,β-unsaturated-δ-lactones.[5] The IR spectrum of IVa displays no free —OH peak, indicating a strongly hydrogen bonded OH group; in this respect being similar to 4-hydroxycoumarin and dimeric carboxylic acids. The band at 7·55 μ may be due to the —OH in plane deformation frequency as observed in 4-hydroxycoumarin.[5] In the region of >C=O absorption, the strong peak at 5·87 μ is in agreement with the spectra of α,β-unsaturated-δ-lactones, and shows that the >C=O group of the lactone is not involved in the hydrogen bonding.

The 3-acetyl derivative (IVb), as the 3-acetyl-4-hydroxycoumarin, condenses with benzaldehyde and with anisaldehyde to give 3-cinnamoyl- (VIIIa) and 3-*p*-methoxycinnamoyl-4-hydroxy-2-oxo-2H-pyrano[3,2-b]thianaphthene (VIIIb), respectively.



VIII a, $R=C_6H_5$
b, $R=C_6H_4OCH_3$-p

3-Nitro-4-hydroxy-2-oxo-2H-pyrano[3,2-b]thianaphthene (IVg) is obtained by the action of nitric acid on IVa.[18] The corresponding 3-acetamido derivative (IVh) is readily formed by the reductive acetylation of either IVg or the 3-phenylazo derivative (IVi). The 3-arylazo derivatives (IVi–k) were obtained by coupling the appropriate diazonium chloride with IVa.[18]

The 4H-pyrano[3,2-b]thianaphthenes, namely, 2-(3′,4′-methylenedioxyphenyl)-(Xa), 2-(3′,4′-diethoxyphenyl)- (Xb), and 2-(4′-chlorophenyl)-4-oxo-4H-pyrano[3,2-b]thianaphthene (Xc), have been synthesized via the selenium dioxide oxidation[19] of the chalcones (IXd–f), respectively. Apparently, the chalcones are first converted into the corresponding dihydro derivatives, which undergo ready transformation into Xa-c.[20]

The IR spectrum of Xc, taken as an example, shows a peak at 6·0 μ characteristic of γ-pyrones and attributed to α,β,α′,β′-diunsaturated >C=O group;[21] it is identical with that of α-naphthoflavone.

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[16] J. Klosa, *Arch. Pharm.* **286**, 37 (1953); **288**, 356 (1955); **289**, 104 (1956); N. S. Vul'fson and R. B. Zhurin, *Zh. Obshch. Khim.* **31**, 281 (1961); *Chem. Abstr.* **55**, 24759 (1961).

[17] H. R. Fisenhauer and K. P. Link, *J. Amer. Chem. Soc.* **75**, 2046 (1953).

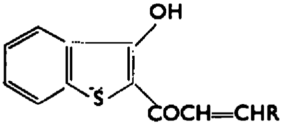
[18] C. F. Huebner and K. P. Link, *J. Amer. Chem. Soc.* **67**, 99 (1945).

[19] S. R. Parikh and N. M. Shah, *J. Indian Chem. Soc.* **36**, 729 (1959); H. S. Mahal, H. S. Rai and K. Venkataraman, *J. Chem. Soc.* 866 (1935); H. S. Mahal and K. Venkataraman, *Ibid.* 569 (1936).

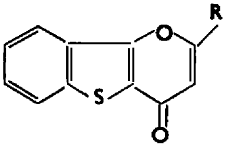
[20] R. C. Elderfield, *Heterocyclic Compounds* Vol. II, p. 246. J. Wiley, New York (1951).

[21] H. W. Tompson and P. Torkington, *J. Chem. Soc.* 640 (1945).

The reactivity of the α,β-unsaturated system in IXa–e toward aromatic thiols in the



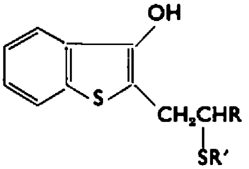
IX a, R=C_6H_5
b, R=$C_6H_4OCH_3$-p
c, R=$C_6H_4CH_3$-p
d, R=$C_6H_3O_2CH_2$-3,4
e, R=$C_6H_3(OC_2H_5)_2$-3,4
f, R=C_6H_4Cl-p



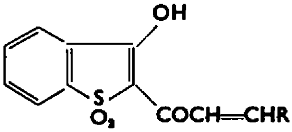
X a, R=$C_6H_3O_2CH_2$-3,4
b, R=$C_6H_3(OC_2H_5)_2$-3,4
c, R=C_6H_4Cl-p

presence of piperidine has been investigated, leading to the formation of well defined crystals of the corresponding β-sulfides (XIa–k),

In view of the well established mechanism for the addition of thiols to analogous α,β-unsaturated compounds,[22] structure XI is proposed for the thiol adducts. The adduct (XIj) undergoes thiol elimination upon treatment with alcoholic potassium hydroxide, whereas with hydrogen peroxide in acetic acid a mixture of XIIb and IXd is formed.



XI a, R=$C_6H_4OCH_3$-p; R′=C_6H_5
b, R=$C_6H_4OCH_3$-p; R′=$C_6H_4CH_3$-m
c, R=$C_6H_4OCH_3$-p; R′=$C_6H_4CH_3$-p
d, R=$C_6H_4CH_3$-p; R′=C_6H_5
e, R=$C_6H_4CH_3$-p; R′=$C_6H_4CH_3$-m
f, R=R′=$C_6H_4CH_3$-p
g, R=$C_6H_3O_2CH_2$-3,4; R′=C_6H_5
h, R=$C_6H_3O_2CH_2$-3,4; R′=$C_6H_4CH_3$-o
i, R=$C_6H_3O_2CH_2$-3,4; R′=$C_6H_4CH_3$-m
j, R=$C_6H_3O_2CH_2$-3,4; R′=$C_6H_4CH_3$-p
k, R=$C_6H_3(OC_2H_5)_2$-3,4; R′=$C_6H_4CH_3$-p



XII a, R=$C_6H_4OCH_3$-p
b, R=$C_6H_3O_2CH_2$-3,4

On the other hand, 2-(4′-methoxycinnamoyl)- (XIIa) and 2-(3′-4′-methylenedioxy-cinnamoyl)-3-hydroxythianaphthene 1,1-dioxide (XIIb), obtained by the action of hydrogen peroxide on IXb and IXd, respectively, form unstable thiol adducts with *p*-thiocresol. Treatment of the coloured XIIa with *p*-thiocresol in the presence of piperidine under the same experimental conditions, effects decolourization, but working up of the reaction mixture resulted in the isolation of XIIa.

EXPERIMENTAL

M.ps. are not corrected. The IR spectra were carried out in Nujol on a Perkin-Elmer infra-cord spectrophotometer Model 137.

6-Acetyl-5-hydroxy-2,3-diphenylbenzofuran (IIIe)

A mixture of IIIb[23] (0·6 g), anhydrous $AlCl_3$ (1 g) and dry nitrobenzene (10 ml) was kept at room temp for 5 days. The product was dried and extracted with hot benzine (b.p. 100–140°). The extract

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[22] T. Posner, *Ber. Dtsch. Chem. Ges.* **35**, 809 (1902); B. H. Nicolet, *J. Amer. Chem. Soc.* **53**, 3066 (1931); R. M. Ross, *Ibid.* **71**, 3458 (1949); R. M. Ross and F. W. Raths, *Ibid.* **73**, 129 (1951); R. M. Ross, H. L. Bushey and R. J. Rolih, *Ibid.* 540 (1951).

[23] O. Dischendorfer, *Monatsh.* **66**, 201 (1935).

TABLE 1. 3-ACYL-4-HYDROXY-2-OXO-2H-PYRANO[3,2-b]THIANAPHTHENES (IVb–f)

Compound	Yield %	M.p.	Solvent for crystn.	Formula	Analyses Carbon Calc.	Carbon Found	Hydrogen Calc.	Hydrogen Found
IVb	76	189–190	A	$C_{13}H_8O_4S$	59·99	59·71	3·10	3·07
c	65	180–181	A	$C_{14}H_{10}O_4S$	61·30	61·12	3·68	3·40
d	76	170–171	A	$C_{15}H_{12}O_4S$	62·47	62·17	4·20	4·07
e	70	172–173	A	$C_{15}H_{12}O_4S$	62·47	63·01	4·20	4·09
f	71	205	B	$C_{19}H_{12}O_4S$	67·84	67·57	3·60	3·82

A, acetic acid; B, Dioxan.

was cooled and the product crystallized from ethanol to give IIIe as golden-yellow crystals, m.p. 157°; yield, 73%. (Found: C, 80·2; H, 5·0. $C_{22}H_{16}O_3$ requires: C, 80·48; H, 4·87%).

A cooled suspension of IIIa (2·8 g) and anhydrous $AlCl_3$ (3·5 g) in nitrobenzene (25 ml) was treated with acetyl chloride (8 ml) under the above conditions. The benzine extract of the product gave upon cooling colourless crystals which were recrystallized from benzene, m.p. 291°; yield, 12%. (Found: C, 80·3; H, 4·9. $C_{22}H_{16}O_3$ requires: C, 80·48; H, 4·87%). Concentration of the benzine mother liquor gave 65% of IIIe.

6-*Cinnamoyl-5-hydroxy-2,3-diphenylbenzofuran* (IIIg)

Compound IIIc was obtained by refluxing a mixture of IIIa (2·8 g), cinnamoyl chloride (1·86 g) and anhydrous $AlCl_3$ (3·4 g) in CS_2 (25 ml), for 3 hr. The reaction mixture yielded a solid on cooling the petroleum ether (b.p. 40–60°) extract and this crystallized from ethanol as yellow crystals, m.p. 132°, yield 95%. (Found: C, 83·4; H, 5·0. $C_{29}H_{20}O_3$ requires: C, 83·65; H, 4·83%).

Treatment of IIIc with $AlCl_3$ as described for IIIe gave a 65% yield of IIIg, as yellow-orange crystals from ethanol, m.p. 184°. It gives a reddish brown colour with $FeCl_3$aq. (Found: C, 83·4; H, 5·0. $C_{29}H_{20}O_3$ requires: C, 83·65; H, 4·83%).

Compound IIIg was also obtained in 85% yield by treatment of IIIa with cinnamoyl chloride under the Friedel-Crafts conditions.

2,3-*Diphenyl-8-hydroxy-6H-furano*[2,3-g][1]*benzopyran-6-one* (I)

A mixture of IIIe, (1 g), ethyl carbonate (4 ml) and Na (0·5 g) in small pieces was shaken at room temp for 5 min then heated on a boiling water-bath for 4 hr. The solid mass was cooled, dissolved in water and extracted with ether. The aqueous layer was acidified with cold dil. HClaq, and the product crystallized from ethanol, as buff crystals (0·7 g) of I, m.p. 288–290° (dec). It does not give a distinct colour with $FeCl_3$aq, dissolves in $NaHCO_3$aq, and its alcoholic solution shows a violet fluorescence. (Found: C, 77·7; H, 4·1. $C_{23}H_{14}O_4$ requires: C, 77·96; H, 3·95%).

6-*Acetoacetyl-5-hydroxy-2,3-diphenylbenzofuran* (IIIf)

A mixture of IIIe (1 g) in ethyl acetate (20 ml) and Na (1 g), in small pieces was refluxed for 1 hr, decomposed with ice and finally extracted with ether. The aqueous layer, on acidification with HClaq, gave a 82% yield of IIIf, which forms pale yellow needles from ethanol, m.p. 159°; its alcoholic solution gives a deep greenish brown colour with $FeCl_3$aq. (Found: C, 77·9; H, 4·8. $C_{24}H_{18}O_4$ requires: C, 77·84; H, 4·86%).

2,3-*Diphenyl-6-methyl-8H-furano*[2,3-g][1]*benzopyran-8-one* (II)

A solution of IIIf (1 g) in 25% H_2SO_4aq (30 ml) was refluxed for 1 hr. The product, after neutralization with Na_2CO_3, was crystallized from ethanol, m.p. 211–212°; yield 77%. Compound II

TABLE 2. 3-AMINO OR IMINO DERIVATIVES OF 3-ACYL-4-HYDROXY-2-OXO-2H-PYRANO[3,2-b]THIANAPHTHENES (VII)

					Analyses							
			Solvent		Carbon		Hydrogen		Nitrogen		Sulphur	
Compound	Yield %	M.p.	for Crystn.	Formula	Calc.	Found	Calc.	Found	Calc.	Found	Calc.	Found
VIIa	80	288–290	A	$C_{13}H_9NO_3S$	60·21	59·83	3·50	3·79	5·40	5·55	12·37	12·18
b	73	224	B	$C_{15}H_{13}NO_3S$	62·69	62·74	4·56	4·73	4·88	4·99	11·16	11·05
c	90	128–129	C	$C_{17}H_{17}NO_3S$	64·72	64·76	5·43	5·60	4·44	4·61	10·16	10·06
d	83	139–140	C	$C_{17}H_{17}NO_3S$	64·72	64·66	5·43	5·34	4·44	4·49	10·16	10·05
e	90	109–110	C	$C_{17}H_{17}NO_3S$	64·72	64·75	5·43	5·27	4·44	4·62	10·16	9·96
f	82	228–230	D	$C_{20}H_{15}NO_3S$	68·76	68·67	4·33	4·19	4·01	3·94	9·18	9·04
g	80	200	B	$C_{20}H_{15}NO_3S$	68·76	69·23	4·33	4·58	4·01	3·99	9·18	8·85
h	72	145	B	$C_{21}H_{17}NO_3S$	69·40	69·38	4·72	4·96	3·68	4·01	8·82	8·64

A, xylene; B, ethanol; C, aqueous ethanol; D, acetic acid.

TABLE 3

				Analyses					
				Carbon		Hydrogen		Sulphur	
Compound	Yield %	M.p.	Formula	Calc.	Found	Calc.	Found	Calc.	Found
			2-Cinnamoyl-3-hydroxythianaphthenes (IX)						
IXa	50	154	$C_{17}H_{12}O_2S$	72·85	73·12	4·28	4·31	11·42	11·64
d	60	175	$C_{18}H_{14}O_2S$	69·68	69·56	4·52	4·78	10·32	10·51
c	65	130	$C_{18}H_{14}O_2S$	73·46	73·57	4·76	4·58		
d	75	199	$C_{18}H_{12}O_4S$	66·66	66·71	3·70	3·83		
e	50	150	$C_{21}H_{20}O_4S$	68·47	68·36	5·43	5·51		
f	70	166	$C_{17}H_{11}ClO_2S$	64·86	65·01	3·49	3·60		
			2-aryl-4-oxo-4H-pyrano[3,2-b]thianaphthenes (X)						
Xa	80	266–267	$C_{18}H_{10}O_4S$	67·08	67·01	3·10	3·30	9·93	10·02
d	65	170–171	$C_{21}H_{18}O_4S$	68·85	69·07	4·91	5·40	8·74	8·72
c	80	235	$C_{17}H_9ClO_2S$	65·38	65·74	2·88	3·03	10·25	10·24

TABLE 4. 2-(β-ARYL-β-ARYLMERCAPTOPROPIONYL)-3-HYDROXYTHIANAPHTHENES (XI)

					Analyses					
					Carbon		Hydrogen		Sulphur	
Compound	Yield	M.p.	Solvent for Crystn.	Formula	Calc.	Found	Calc.	Found	Calc.	Found
XIa	55	128–130	A	$C_{24}H_{20}O_3S_2$	68·57	68·56	4·76	4·78	15·23	14·91
b	60	86–87	B	$C_{25}H_{22}O_3S_2$	69·12	69·18	5·06	5·08	14·74	14·55
c	60	101–102	B	$C_{25}H_{22}O_3S_2$	69·12	69·24	5·06	5·20	14·74	14·42
d	55	110–112	A	$C_{24}H_{20}O_2S_2$	71·28	71·35	4·95	5·11	15·84	15·93
e	60	92–93	B	$C_{25}H_{22}O_2S_2$	71·77	71·65	5·26	5·34	15·31	15·50
f	60	105–106	B	$C_{25}H_{22}O_2S_2$	71·77	71·66	5·26	5·39	15·31	15·53
g	58	125–126	A	$C_{24}H_{18}O_4S_2$	66·35	65·99	4·14	4·24	14·74	14·69
h	60	132–133	A	$C_{25}H_{20}O_4S_2$	66·96	66·84	4·46	4·23	14·28	14·41
i	60	106	A	$C_{25}H_{20}O_4S_2$	66·96	67·13	4·46	4·51	14·28	13·87
j	60	135–136	A	$C_{25}H_{20}O_4S_2$	66·96	67·12	4·46	4·36	14·28	14·52
k	50	105	B	$C_{28}H_{28}O_4S_2$					13·00	12·74

A, acetic acid; B, ethanol.

gives a yellow colour with Mg and HClaq,[24] a stable purple colour with *m*-dinitrobenzene and alkali,[25] and a positive KOH test.[26] (Found: C, 81·4; H, 4·6. $C_{24}H_{16}O_3$ requires: C, 81·81; H, 4·54%).

5-Allyloxy-2,3-diphenylbenzofuran (IIId)

A mixture of IIIa (2·8 g), allyl bromide (2·5 ml) and anhydrous K_2CO_3 (10 g) in dry acetone (50 ml) was refluxed for 12 hr. The reaction mixture was filtered hot, the filtrate evaporated and the residue crystallized from pet. ether (b.p. 60–80°) to give colourless crystals of IIId, m.p. 72°; yield 55%. (Found: C, 84·6; H, 5·5. $C_{23}H_{18}O_2$ requires: C, 84·66; H, 5·52%).

6-Allyl-5-hydroxy-2,3-diphenylbenzofuran (IIIh)

Refluxing a solution of IIId (1 g) in dimethylaniline (7 ml) for 3 hr, cooling, then acidifying with dil. HClaq, gave a colourless solid, which upon crystallization from pet. ether (b.p. 60–80°), yielded 0·5 g of IIIh, m.p. 83°. It gives a red colour with conc. H_2SO_4. (Found: C, 84·2; H, 5·5. $C_{23}H_{18}O_2$ requires: C, 84·66; H, 5·52%).

[24] Y. Asahina and M. Inubuse, *Ber. Dtsch. Chem. Ges.* **61**, 1646 (1928).
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[26] A. Schönberg and A. Sina, *J. Chem. Soc.* 3344 (1950); *J. Amer. Chem. Soc.* **72**, 1611 (1950).

Experiments with amines

(a) 4-*Hydroxy*-2-*oxo*-2H-*pyrano*[3,2-b]*thianaphthene* (IVa). A mixture of IVa[9a] (1 g), aniline (1 ml) and ethanol 20 ml (method A) or in absence of ethanol was heated (water-bath) for 4 hr. The reaction product (Va; 85%) was crystallized from ethanol in pale yellow crystals, m.p. 188–190°. (Found: C, 65·5; H, 4·3; N, 4·5; S, 10·1. $C_{17}H_{13}NO_3S$ requires: C, 65·58; H, 4·21; N, 4·50; S, 10·30%).

A mixture of Va (0·6 g) and aniline (1 ml) was heated at 180° for 1·5 hr (method B). The reaction mixture was triturated with cold ethanol and the product fractionally crystallized from ethanol to give IVl. Concentration of the mother liquor deposited yellow crystals of VI, which were recrystallized from the same solvent, m.p. 222°. It gives a green colour with $FeCl_3$aq. (Found: C, 71·6; H, 4·8; N, 7·2. $C_{23}H_{18}N_2O_2S$ requires: C, 71·48; H, 4·69; N, 7·25%).

Compound Vb was obtained in 60% yield from IVa and *p*-toluidine (method A); and crystallized from ethanol, m.p. 199°. (Found: C, 66·2; H, 5·1; N, 4·4; S, 9·7. $C_{18}H_{15}NO_3S$ requires: C, 66·43; H, 4·65; N, 4·31; S, 9·85%).

Heating IVa and *p*-toluidine (method B) resulted in a 71% yield of IVm; crystallized from ethanol, m.p. 269–70°. (Found: C, 70·3; H, 4·3; N, 4·4; S, 10·3. $C_{18}H_{13}NO_2S$ requires: C, 70·34; H, 4·26; N, 4·56; S, 10·43%).

(b) 4-*Benzoyloxy*-2-*oxo*-2H-*pyrano*[3,2-b]*thianaphthene* (IVo). It was obtained in 75% yield from IVa and benzoyl chloride according to Eisenhauer and Link,[17] and crystallized from ethanol, m.p. 162°. (Found: C, 66·7; H, 3·3. $C_{18}H_{10}O_4S$ requires: C, 67·07; H, 3·13%). Treatment of IVo with aniline (method A) gave Va in 60% yield.

(c) 4-*Chloro*-2-*oxo*-2H-*pyrano*[3,2-b]*thianaphthene* (IVn). A mixture of IVn[9b] (0·5 g) and aniline (1 ml) was treated as in method A and IVl obtained; m.p. 280° (Smiles and Hart [9b] gave m.p. 280°).

(d) 3-*Acyl*-4-*hydroxy*-2-*oxo*-2H-*pyrano*[3,2-b]*thianaphthene*.

Preparation of the acyl derivatives (IVb–f)

General Procedure. A mixture of IVa (0·01 mole), the appropriate acid (8 ml) and $POCl_3$ (10 ml) was refluxed for 45 min. The reaction mixture was then poured onto ice, and the product washed thoroughly with cold water. The acyl derivatives, listed in Table 1, are soluble in NaOHaq and in $NaHCO_3$aq and give a red colour with $FeCl_3$aq.

Refluxing a solution of IVb–d (0·5 g) with excess of the appropriate amine in ethanol (30 ml) for 3–4 hr (in the case of ammonium acetate, 8 hr), resulted in the corresponding amino or imino derivatives (VIIa–h) listed in Table 2. The reaction products separated upon cooling the mixture or were obtained by evaporation. They do not develop a colour with $FeCl_3$aq.

A mixture of IVb (0·5 g) and as-methylphenylhydrazine (0·5 g) in ethanol (20 ml) was refluxed for 3 hr and cooled. The product was crystallized from ethanol as yellow crystals of VIIi, m.p. 168°; yield 82%. (Found: C, 66·3; H, 4·6; N, 7·7; S, 8·5. $C_{20}H_{16}N_2O_3S$ requires: C, 65·92; H, 4·43; N, 7·69; S, 8·80%).

Action of aromatic aldehydes on IVb. Compound VIIIa was obtained by heating IVb (0·5 g) and benzaldehyde (0·25 g) in presence of one drop of piperdine, for 1 hr on the water-bath. It formed orange crystals from a mixture of dioxan and water, m.p. 230°, yield 65%. (Found: C, 68·6; H, 3·7; S, 9·5. $C_{20}H_{12}O_4S$ requires: C, 68·96; H, 3·47; S, 9·20%).

Similarly, VIIIb was obtained in 60% yield as orange crystals from dioxan, m.p. 220°. (Found: C, 67·1; H, 3·9. $C_{21}H_{14}O_5S$ requires: C, 66·65; H, 3·73%).

3-*Acetamido*-4-*hydroxy*-2-*oxo*-2H-*pyrano*[3,2-b]*thianaphthene* (IVh). Compound IVa (1 g) in acetic acid (10 ml) was treated with HNO_3 (*d*, 1·42; 3 ml) and left overnight at room temp. Compound IVg (1 g) was washed with cold acetic acid and crystallized from the same solvent; m.p. 215°. (Found: C, 50·3; H, 2·0; N, 5·3; S, 12·0. $C_{11}H_5NO_5S$ requires: C, 50·19; H, 1·91; N, 5·32; S, 12·18%).

A mixture of IVg (0·5 g), Zn dust (0·5 g), acetic acid (5 ml) and acetic anhydride (5 ml) was refluxed for 4 hr. The reaction mixture was poured into ice-water and the product was crystallized from acetic acid to yield 0·4 g of IVh, m.p. 250–252°. (Found: N, 4·8; S, 11·5. $C_{13}H_9NO_4S$ requires: N, 5·09; S, 11·65%).

3-*Arylazo*-4-*hydroxy*-2-*oxo*-2H-*pyrano*[3,2-b]*thianaphthenes* (IVi–k). A mixture of a cold solution of IVa (1 g) in ethanol (100 ml) and crystalline sodium acetate (2·5 g) was treated with the appropriate aryl diazonium chloride (0·005 mole) and left overnight and the product filtered off.

3-*Phenylazo-4-hydroxy-2-oxo-*2H-*pyrano*[3,2-b]*thianaphthene* (IVi). This forms orange-red crystals from acetic acid, m.p. 260°; yield 94%. (Found: C, 63·5; H, 2·9; N, 8·8; S, 9·8. $C_{17}H_{10}N_2O_3S$ requires: C, 63·34; H, 3·13; N, 8·69; S, 9·95%).

Reductive acetylation of IVi (0·5 g) as mentioned above, gave a 70% yield of IVh (m.p. and mixed m.p.).

3-p-*Tolylazo-4-hydroxy-2-oxo-*2H-*pyrano*[3,2-b]*thianaphthene* (IVj). This forms red crystals from acetic acid, m.p. 250°; yield 84%. (Found: N, 8·3; S, 9·5. $C_{18}H_{12}N_2O_3S$ requires: N, 8·56; S, 9·86%). The 3-p-*chlorophenylazo analog* (IVk) was obtained as red crystals from acetic acid, m.p. 257°; yield 85%. (Found: C, 56·8; H, 2·5; N, 7·6. $C_{17}H_9ClN_2O_3S$ requires: C, 57·23; H, 2·54; N, 7·85%).

2-*Cinnamoyl-*3-*hydroxythianaphthene* (IXa–f)

General procedure. To a solution of 2-acetyl-3-hydroxythianaphthene[9a] (0·001 mole) in ethanol (10 ml) the appropriate aldehyde (0·0015 mole) and 10% alcoholic NaOH (1:1; 4 ml) was added. The reaction mixture was refluxed for ½ hr and kept at room temp. It was then acidified with cold dil. HCl, and the product filtered off, washed with water, dried, and crystallized from acetic acid (cf. Table 3).

2-*Aryl-4-oxo-*4H-*pyrano*[3,2-b]*thianaphthenes* (Xa–c)

General procedure. A mixture of each of the chalcones, (IXd–f; 0·5 g), SeO_2 (0·5 g), and dry isoamyl alcohol (8 ml) was refluxed for 10–15 hr. It was filtered while hot, the solvent evaporated and the product washed with cold ethanol and crystallized from ethanol (cf. Table 3).

2-(*β-Aryl-β-arylmercaptopropionyl*)-3-*hydroxythianaphthenes* (XIa–k)

General procedure. A mixture of each of the chalcones (IXb–e; 0·5 g), the appropriate thiol (0·5 g) and 1–2 drops piperidine, was heated (water-bath) for 4 hr. It was then cooled, triturated with pet. ether (b.p. 40–60°) and the product filtered off and crystallized from the proper solvent (cf. Table 4).

Action of alcoholic potassium hydroxide on XId. To a suspension of XId (0·5 g) ethanol (10 ml) alcoholic KOHaq (5%; 3 ml) was added. The reaction mixture was refluxed for ½ hr, cooled and the product filtered off, suspended in cold ethanol (10 ml) and acidified with cold dil. HClaq. The product (0·32 g) was crystallized from acetic acid to give IXc (m.p. and mixed m.p.).

Action of hydrogen peroxide on IXb *and* IXd. A mixture of each of IXb and IXd (0·5 g) in glacial acetic acid (40 ml) and H_2O_2 (30%; 1 ml) was heated at 80° (water-bath) for 15 min. The cooled reaction mixture was poured into ice-water and the product collected.

2-p-*Methoxycinnamoyl-*3-*hydroxythianaphthene* 1,1-*dioxide* (XIIa)

This crystallized from acetic acid, m.p. 215°; yield 61%. (Found: C, 62·9; H, 4·2; S, 9·1. $C_{18}H_{14}O_5S$ requires: C, 63·15; H, 4·09; S, 9·41%).

2-(3′,4′-*methylenedioxycinnamoyl*)-3-*hydroxythianaphthene* 1,1-*dioxide* (XIIb)

This was crystallized from chlorobenzene, m.p. 271–273°; yield 70%. (Found: C, 60·6; H, 3·6; S, 8·8. $C_{18}H_{12}O_6S$ requires: C, 60·7; H, 3·37; S, 8·98%).

Compound XIIb was also obtained, in 52% yield, upon treatment of the thiol adduct, XIj, with H_2O_2 in acetic acid.

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