197. *Thionaphthen Derivatives. Part III.* Characterisation of Some 5-Substituted Derivatives.*

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Certain substitution products of various 5-substituted thionaphthens are reported. The compound previously considered as 4-bromo-5-hydroxy-3-nitrothionaphthen is shown to be the 6-nitro-derivative, and the compound previously reported as 7-bromo-5-nitrothionaphthen-2-carboxylic acid is shown to be 3-bromo-acid. The structure of the by-product from application of the Bucherer reaction to 5-aminothionaphthen-2-carboxylic acid has been proved.

In an investigation of thionaphthen derivatives as possible biologically active compounds, it was necessary to characterise various derivatives of some 5-substituted thionaphthens.

5-Hydroxythionaphthen underwent mononitration in cold acetic acid to form 5-hydroxy-4-nitrothionaphthen, the constitution of which was proved by an alternative synthesis from the known 5-amino-4-nitrothionaphthen [1] employing nucleophilic displacement of the amino-group. 5-Hydroxythionaphthen-2-carboxylic acid was shown also to be nitrated directly in the 4-position, the product being identical with an authentic

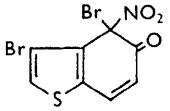
* References 2 and 5 are regarded as Parts I and II of this series.

[1] Bordwell and Stange, *J. Amer. Chem. Soc.*, 1955, **77**, 5939.
[2] Martin-Smith and Gates, *ibid.*, 1956, **78**, 5351.

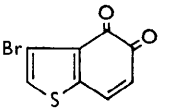
specimen of 5-hydroxy-4-nitrothionaphthen-2-carboxylic acid.[2] Similarly 3-bromo-5-hydroxy-4-nitrothionaphthen was obtained by mononitration of the 3-bromo-5-hydroxy-compound in acetic acid. The structure of the product was apparent from its infrared spectrum in carbon tetrachloride solution at a dilution sufficient to ensure absence of intermolecular hydrogen bonding (0·5 mg./ml.). The OH stretching frequency at 3290 cm.$^{-1}$ showed chelation of the nitro- and hydroxyl groups, thus proving their *ortho*-relation. Reduction of the compound, followed by oxidation, gave the 4,5-quinone characterised by the Craven test.[3] With excess of nitric acid, 3-bromo-5-hydroxythionaphthen formed a dinitro-derivative of which the constitution has not been established.

Nitration of 4-bromo-5-hydroxythionaphthen has been stated [4] to yield the 3-nitro-compound, but as bromination of 4-bromo-5-hydroxythionaphthen yields the 4,6-dibromo-compound [5] the nitration product was re-investigated. A study of the infrared spectrum in carbon tetrachloride (1·1 mg./ml.) showed that the fundamental OH stretching frequency was at 3211 cm.$^{-1}$, proving that the hydroxyl and nitro-groups were chelated and that the compound was indeed 4-bromo-5-hydroxy-6-nitrothionaphthen. The true 4-bromo-5-hydroxy-3-nitrothionaphthen was prepared from 5-benzoyloxythionaphthen by nitration, followed by hydrolysis to the free phenol and monobromination. The OH stretching frequency of this product at *ca.* 3580 cm.$^{-1}$ in carbon tetrachloride solution (1·1 mg./ml.) confirmed the non-adjacent relationship of the hydroxyl and the nitro-groups.

The course of nitration of 4-bromo-5-hydroxythionaphthen is nevertheless interesting, as under the same experimental conditions 3,4-dibromo-5-hydroxythionaphthen yields



(I)



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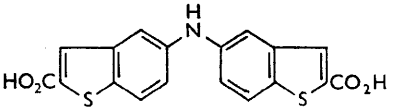

(III)

the keto-compound (I) which is converted into the quinone (II) in boiling benzene.[2] Formation of the intermediate (I) may be favoured by steric considerations, as the 3- and the 4-position of thionaphthen are analogous to the *peri*-positions in naphthalene and removal of the 4-substituent from the plane of the ring system would afford a method of relieving the steric interaction with the 3-substituent.

The action of nitric acid on 4,6-dibromo-5-hydroxythionaphthen was previously assumed [5] to give a keto-compound of type (I) as intermediate, in order to explain the formation of 6-bromothionaphthen-4,5-quinone when the nitration was carried out in chloroform, and of 6-bromo-5-hydroxy-4-nitrothionaphthen in acetic acid. This unstable keto-compound has now been isolated, and it was characterised by conversion into the 4,5-quinone in boiling benzene.

On bromination in acetic acid in the presence of sodium acetate, 5-amino-4-bromothionaphthen gave a crystalline dibromo-compound which was shown to be 5-amino-4,6-dibromothionaphthen by an alternative synthesis from 5-amino-4-bromothionaphthen-2-carboxylic acid. In this case the 3-position is deactivated towards electrophilic attack by the presence of the carboxylic group in the 2-position and, after bromination and decarboxylation, 5-amino-4,6-dibromothionaphthen is obtained unambiguously. 5-Acetamido-4-bromothionaphthen is, however, brominated in the 3-position as was proved by hydrolysis of the product to an amine which was prepared also from 5-amino-3-bromothionaphthen. 4-Bromo-5-methoxythionaphthen, obtained both by monobromination of 5-methoxythionaphthen and by methylation of 4-bromo-5-hydroxythionaphthen, also gives on bromination the 3-substituted product, as was proved by direct comparison with

[3] Craven, *J.*, 1931, 1605.
[4] Fries, Heering, Hemmecke, and Siebert, *Annalen*, 1936, **527**, 83.
[5] Martin-Smith and Gates, *J. Amer. Chem. Soc.*, 1956, **78**, 6177.

authentic 3,4-dibromo-5-methoxythionaphthen prepared by the methylation of 3,4-dibromo-5-hydroxythionaphthen. Under the same conditions, 5-methoxy-4-nitrothionaphthen did not take up bromine. It is of interest that bromination of 5-hydroxy-4-nitrothionaphthen both in the presence and in the absence of sodium acetate yields quininoid material.

Methyl 5-acetoxythionaphthen-2-carboxylate was found to be unreactive towards both bromine and nitric acid in hot acetic acid, but nitration of 5-nitrothionaphthen-2-carboxylic acid in hot acetic acid in the presence of concentrated sulphuric acid gave a complex mixture from which two isomeric trinitrothionaphthens containing no carboxyl group were isolated in low yield.

Sodium 5-nitrothionaphthen-2-carboxylate was reported to undergo bromination in aqueous solution,[2] the acid obtained being identical with the main product from an attempted Hunsdiecker reaction [6] on 5-nitrothionaphthen-2-carboxylic acid. This compound has now been shown to be 3-bromo- and not 7-bromo-5-nitrothionaphthen-2-carboxylic acid as previously suggested,[2] by decarboxylation *via* the barium salt to 3-bromo-5-nitrothionaphthen.[7] Application of the Hunsdiecker reaction to 3-bromo-5-nitrothionaphthen-2-carboxylic acid gave 2,3-dibromo-5-nitrothionaphthen identical with the compound previously regarded as 2,7-dibromo-5-nitrothionaphthen.[2]

In this work, the reduction of nitro-compounds to the corresponding amines was usually accomplished by Raney nickel and hydrazine hydrate.[8] When this method was applied to methyl 3-bromo-5-nitrothionaphthen-2-carboxylate, however, debromination occurred, and methyl 5-acetamidothionaphthen-2-carboxylate was isolated after acetylation of the crude product. Preliminary experiments indicated that application of the reaction to general aromatic debromination was not satisfactory, especially in view of the adequate methods already available.[9]

The by-product formed by application of the Bucherer reaction to 5-aminothionaphthen-2-carboxylic acid has been shown to be di-(2-carboxy-5-thionaphthenyl)amine(III). The reason for the bright yellow colour shown by this compound is not readily apparent. The anion lacks this colour, and the disodium salt, as well as a solution of the acid in pyridine, is nearly colourless. In this connexion it is to be noted that 5-amino-4-bromo- and 5-amino-4,6-dibromo-thionaphthen-2-carboxylic acid exist in both colourless and yellow forms. The structure of the amine (III) was established by decarboxylation to 5,5′-dithionaphthenylamine which was identical with a specimen prepared unambiguously by heating equal quantities of 5-aminothionaphthen and 5-aminothionaphthen hydrochloride in a sealed tube.[10] Attempts to prepare the compound by way of 5-iodothionaphthen were unsuccessful.

Experimental

5-Hydroxy-4-nitrothionaphthen.—5-Acetamido-4-nitrothionaphthen [1] (2·29 g., 9·7 mmoles) was dissolved in Claisen's alkali [11] (35 g. of potassium hydroxide in 25 ml. of water and 100 ml. of methanol) and boiled under reflux for 5 hr. Ammonia was liberated and, on cooling, a potassium salt crystallised. *5-Hydroxy-4-nitrothionaphthen* was obtained as light yellow needles by acidifying an aqueous solution of the potassium salt, and after recrystallisation from ethanol (1·61 g., 85%) had m. p. 119—121° (Found: C, 49·2; H, 2·3. $C_8H_5NO_3S$ requires C, 49·2; H, 2·6%).

5-Hydroxy-4-nitrothionaphthen was also obtained by the direct nitration of 5-hydroxythionaphthen.[4] To 5-hydroxythionaphthen (0·114 g., 0·76 mmole) dissolved in acetic acid (5 ml.)

[6] Hunsdiecker and Hunsdiecker, *Ber.*, 1942, **75**, 291.
[7] Bordwell and Albisetti, *J. Amer. Chem. Soc.*, 1948, **70**, 1955.
[8] Balcom and Furst, *ibid.*, 1953, **75**, 4334.
[9] See, for example, Mayo and Hurwitz, *ibid.*, 1949, **71**, 776; Smith, *ibid.*, 1953, **75**, 3602; Gilman, *ibid.*, 1951, **73**, 470; Blatt *et al.*, *J. Org. Chem.*, 1957, **22**, 1046, 1588; Blatt and Tristram, *J. Amer. Chem. Soc.*, 1952, **74**, 6273.
[10] De Laire, Girora, and Chapoteaut, *Compt. rend.*, 1866, **63**, 92.
[11] Claisen, *Annalen*, 1919, **418**, 97.

at 10°, concentrated nitric acid (0·048 ml., 0·76 mmole) in acetic acid (5 ml.) was gradually added. A red colour was immediately apparent, and on addition of water orange crystals were obtained. These formed yellow needles (0·070 g., 47%), m. p. 119° and mixed m. p. 119°, from ethanol; infrared spectra of the two samples in Nujol were identical.

5-Hydroxy-4-nitrothionaphthen-2-carboxylic Acid.—5-Hydroxythionaphthen-2-carboxylic acid [2] (0·730 g., 3·8 mmole) was dissolved in acetic acid (20 ml.), and concentrated nitric acid (0·24 ml., 3·8 mmole) gradually added at 10°. Overnight the nitro-compound crystallised. Light yellow needles (0·543 g., 61%) were obtained from ethanol, having m. p. 273° and mixed m. p. with an authentic sample [2] 274°.

3-Bromo-5-hydroxy-4-nitrothionaphthen.—To a solution of 3-bromo-5-hydroxythionaphthen [1] (0·177 g., 0·77 mmole) in acetic acid (20 ml.) at 10°, concentrated nitric acid (0·05 ml., 0·77 mmole) in acetic acid (2·40 ml.) was added. Addition of water precipitated the *nitro-compound* which crystallised as needles (from ethanol) (0·124 g., 59%), m. p. 160° (Found: C, 35·6; H, 1·7. $C_8H_4BrNO_3S$ requires C, 35·1; H, 1·5%). On reduction in ethanol with Raney nickel and hydrazine hydrate, followed by oxidation with potassium ferricyanide, a green colour was obtained with triethylamine and ethyl cyanoacetate, indicating the formation of a 7-(cyano-ethoxycarbonyl)thionaphthen-4,5-quinone.

With excess of concentrated nitric acid, a *dinitro-compound* was formed. 3-Bromo-5-hydroxythionaphthen (34 mg.) was dissolved in acetic acid (1 ml.), and 2 drops of concentrated nitric acid were added. Orange needles crystallised; recrystallisation from ethanol gave a product, m. p. 211—213° (36 mg., 76%) (Found: C, 30·2; H, 1·3. $C_8H_3BrN_2O_5S$ requires C, 30·1; H, 1·0%).

4-Bromo-5-hydroxy-6-nitrothionaphthen.—To 4-bromo-5-hydroxythionaphthen [4] (2·0 g., 8·7 mmole) in acetic acid (20 ml.), concentrated nitric acid (0·55 ml., 8·7 mmole) was added at room temperature. Immediately, *4-bromo-5-hydroxy-6-nitrothionaphthen* crystallised; it formed orange needles, m. p. 175—176° (1·4 g., 58%), from ethanol (Found: C, 35·5; H, 2·0; N, 5·4. $C_8H_4BrNO_3S$ requires C, 35·1; H, 1·5; N, 5·1%).

The *methyl ether*, prepared by reaction with an excess of ethereal-ethanolic diazomethane, formed pale yellow needles (95%), m. p. 114·5°, from ethanol (Found: C, 37·6; H, 1·9. $C_9H_6BrNO_3S$ requires C, 37·6; H, 2·1%).

5-Benzoyloxythionaphthen.—With benzoyl chloride (3·09 g., 0·022 mol.) in ice-cold pyridine for 30 minutes, 5-hydroxythionaphthen (3·33 g., 0·022 mole) gave the *benzoyl derivative*, forming cubic crystals (4·97 g., 88%), m. p. 111·5—113°, from light petroleum (b. p. 60—80°) Found: C, 71·0; H, 4·1. $C_{15}H_{10}O_2S$ requires C, 70·9; H, 4·0%).

5-Benzoyloxy-3-bromothionaphthen.—5-Benzoyloxythionaphthen (0·529 g., 2·0 mmole), sodium acetate (0·35 g., 5·0 mmole), and bromine (0·333 g., 2·0 mmole) were heated in acetic acid (10 ml.) on the steam-bath for 30 min. Addition of water precipitated the crude *bromo-compound*, m. p. 130·5° (0·65 g., 69%) from light petroleum (b. p. 60—80°) (Found: C, 54·0; H, 2·7. $C_{15}H_9BrO_2S$ requires C, 54·1; H, 2·7%).

Hydrolysis in 5% sodium hydroxide solution at 90° gave 3-bromo-5-hydroxythionaphthen in quantitative yield, m. p. 135° and mixed m. p. 135—136°.

5-Benzoyloxy-3-nitrothionaphthen.—To 5-benzoyloxythionaphthen (0·80 g., 3·15 mmole) in acetic acid (10 ml.) containing concentrated sulphuric acid (1 ml.), fuming nitric acid (0·22 ml., 3·5 mmole) was added. Within 2 hr., yellow needles of *5-benzoyloxy-3-nitrothionaphthen* appeared. After crystallisation from ethyl acetate, this had m. p. 180—180·5° (0·65 g., 69%) (Found: C, 60·3; H, 3·0. $C_{15}H_9NO_4S$ requires C, 60·2; H, 3·0%).

5-Hydroxy-3-nitrothionaphthen.—Preliminary attempts to hydrolyse the benzoyl compound with dilute sodium hydroxide solution were unsuccessful. 5-Benzoyloxy-3-nitrothionaphthen (0·70 g., 2·3 mmole) was refluxed in absolute ethanol (200 ml.) containing concentrated hydrochloric acid (3 ml.) for 12 hr. The ethanol was removed under reduced pressure and the product extracted with 2N-sodium hydroxide. On acidification of this solution, the *hydroxy-compound* was precipitated. Fine yellow needles (0·060 g.), m. p. 164·5—166°, were obtained from water, (Found: C, 49·2; H, 2·6. $C_8H_5NO_3S$ requires C, 49·2; H, 2·6%). Starting material (0·47 g.) was recovered.

4-Bromo-5-hydroxy-3-nitrothionaphthen.—To 5-hydroxy-3-nitrothionaphthen (0·043 g., 0·22 mmole) and sodium acetate (0·05 g.) in acetic acid (4 ml.), bromine (0·0353 g., 0·22 mmole) in acetic acid was added at 10°. On addition of water, a pale yellow precipitate of *4-bromo-5-hydroxy-3-nitrothionaphthen* separated; fine yellow needles (0·051 g., 84·5%), m. p. 129—131°,

were formed from light petroleum (b. p. 60—80°) (Found: C, 34·8; H, 1·8. $C_8H_4BrNO_3S$ requires C, 35·1; H, 1·5%).

4,6-*Dibromo*-4,5-*dihydro*-4-*nitro*-5-*oxothionaphthen*.—To 4,6-dibromo-5-hydroxythionaphthen (0·81 g., 2·6 mmole) in acetic acid (5 ml.), concentrated nitric acid (0·40 ml.) was added at 10°. Orange crystals of the keto-compound formed. These were unstable and decomposed after several hours at room temperature. Dilution of an acetic acid solution of the keto-compound with water gave 6-bromo-5-hydroxy-4-nitrothionaphthen, m. p. 124° and mixed m. p. 127°. A positive Craven's test [3] with ethyl cyanoacetate and triethylamine was obtained after boiling in benzene.

5-*Amino*-4,6-*dibromothionaphthen*-2-*carboxylic Acid*.—Bromine (6·64 g., 0·0415 mole) was added to 5-aminothionaphthen-2-carboxylic acid (4·0 g., 0·0207 mole) and sodium acetate (3·1 g.) in hot acetic acid (800 ml.), and the resulting solution heated at 80° for 10 min. On cooling, prisms of the *dibromo-compound* crystallised; pale yellow needles (4·7 g., 65%) from ethanol had m. p. 314° (Found: C, 30·6; H, 1·7. $C_9H_5Br_2NO_2S$ requires C, 30·8; H, 1·4%).

5-*Amino*-4,6-*dibromothionaphthen*.—The barium salt (0·158 g.) of 5-amino-4,6-dibromothionaphthen-2-carboxylic acid was prepared and heated *in vacuo* with barium hydroxide (0·50 g.). At 330°, decarboxylation took place, and 5-*amino*-4,6-*dibromothionaphthen* sublimed on to a cold finger. Colourless crystals (0·038 g., 33%) from ethanol had m. p. 119° (Found: C, 31·4; H, 1·5. $C_8H_5Br_2NS$ requires C, 31·3; H, 1·5%).

5-Amino-4,6-dibromothionaphthen was also obtained from 5-amino-4-bromothionaphthen. To a solution of this compound (0·50 g., 2·2 mmole) in acetic acid (5 ml.) was added bromine (0·35 g., 2·2 mmole) in acetic acid at room temperature, and the crude product was precipitated with water. After recrystallisation from ethanol it had m. p. 119° and mixed m. p. 119° (0·52 g., 77%); infrared spectra of the two samples in Nujol were identical.

3-*Bromo*-5-*nitrothionaphthen*.—5-Nitrothionaphthen (5·0 g., 0·0279 mole), bromine (4·47 g., 0·0279 mole), and sodium acetate (2·3 g.) were heated under reflux for 1 hr. in acetic acid (200 ml.) and, on cooling, red needles of the crude bromo-compound separated. Purification in hot ethanol (charcoal) gave pale yellow needles (5·9 g., 82%), m. p. 171° (lit.,[7] 170—171°).

5-*Amino*-3-*bromothionaphthen*.—3-Bromo-5-nitrothionaphthen (4·59 g., 0·0178 mole) was hydrogenated with shaking in ethanol (250 ml.) at room temperature. Platinum oxide (100 mg.) was used as catalyst. After 2½ hr., 1200 ml. of hydrogen (0·05 mole, 94%) had been taken up. The solution was reduced to 50 ml. and dilute hydrochloric acid added. The *amine hydrochloride* thus precipitated was extracted with hot benzene to remove any unchanged nitro-compound and recrystallised from water as colourless needles (2·64 g., 60%), m. p. 262° (Found: C, 36·2; H, 2·4. $C_8H_7BrClNS$ requires C, 36·3; H, 2·7%).

The free amine had m. p. 80—82°. With acetyl chloride in pyridine at 5° (2 hr.), it gave the *acetyl derivative*, plates (80%), m. p. 164° (from benzene) (Found: C, 44·8; H, 3·2. $C_{10}H_8BrNOS$ requires C, 44·4; H, 3·0%).

5-*Amino*-3,4-*dibromothionaphthen*.—Bromine (0·152 g., 0·95 mmole) in acetic acid (1·2 ml.) was added gradually to a solution of 5-amino-3-bromothionaphthen (0·216 g., 0·95 mmole) in acetic acid (10 ml.). After 5 minutes' heating on the steam-bath, 5-amino-3,4-dibromothionaphthen hydrobromide was precipitated. It was shaken with ether and sodium hydroxide solution, and the *dibromo-amine* obtained from the ethereal solution by removal of the solvent under reduced pressure. White needles (0·210 g., 72%) were formed from light petroleum (b. p. 60—80°) and had m. p. 143° (Found: C, 31·7; H, 1·6. $C_8H_5Br_2NS$ requires C, 31·3; H, 1·6%).

5-*Acetamido*-3,4-*dibromothionaphthen*.—5-Acetamidothionaphthen (0·82 g., 4·3 mmole), bromine (1·36 g., 8·6 mmole), and sodium acetate (0·8 g.) were heated under reflux in acetic acid (40 ml.) for 1 hr. Addition of water precipitated a *dibromo-compound* which formed needles (0·87 g., 58%), m. p. 172°, from benzene (Found: C, 34·5; H, 2·0. $C_{10}H_7Br_2NOS$ requires C, 34·4; H, 2·0%).

Hydrolysis of this compound (105 mg.) in ethanol and 2N-sodium hydroxide (1 : 1) on the steam-bath gave 5-amino-3,4-dibromothionaphthen (81 mg., 90%), m. p. 143° and mixed m. p. 143°. The infrared spectrum in Nujol was identical with that of authentic 5-amino-3,4-dibromothionaphthen.

5-*Methoxythionaphthen*.—Dimethyl sulphate (0·189 g., 1·5 mmole) was added to 5-hydroxythionaphthen (0·217 g., 1·5 mmole) dissolved in 0·1N-sodium hydroxide (14·5 ml.), and the resulting mixture shaken for 1 hr. The methoxy-compound was isolated as an oil by extraction

with ether. White needles (0·12 g., 51%), m. p. 42° (lit.,[4] 44°), were obtained by sublimation at 150° under reduced pressure.

4-Bromo-5-methoxythionaphthen.—5-Methoxythionaphthen (0·079 g., 0·48 mmole), bromine (0·077 g., 0·48 mmole), and sodium acetate (0·08 g.) were warmed in acetic acid (4 ml.) on the steam-bath for 30 min. The *bromo-compound* was precipitated by the addition of water; crystallisation from light petroleum (b. p. 40—60°) gave needles (0·093 g., 80%), m. p. 90° (Found: C, 44·2; H, 2·8. C_9H_7BrOS requires C, 44·5; H, 3·0%).

4-Bromo-5-methoxythionaphthen was also prepared from 4-bromo-5-hydroxythionaphthen by methylation with dimethyl sulphate, then having m. p. 88—89° and mixed m. p. 89°.

3,4-Dibromo-5-methoxythionaphthen.—(*a*) 4-Bromo-5-methoxythionaphthen (0·028 g., 0·115 mmole) was heated in acetic acid with bromine (0·019 g., 0·118 mmole) on the steam-bath for 30 min., and the *3,4-dibromo-5-methoxythionaphthen* was precipitated by water. White crystals (0·027 g., 73%) were obtained from light petroleum (b. p. 40—60°), m. p. 119° (Found: C, 33·9; H, 2·1. $C_9H_6Br_2OS$ requires C, 33·6; H, 1·9%).

(*b*) 3,4-Dibromo-5-hydroxythionaphthen [1] (0·37 g., 1·2 mmole) was shaken with 0·1N-sodium hydroxide (12 ml.) and dimethyl sulphate (0·164 g., 1·3 mmole) for 1 hr. The methoxy-compound, obtained by extraction with ether, had m. p. and mixed m. p. 122° (0·15 g., 70%) [from light petroleum (b. p. 40—60°)]. Starting material (0·18 g.) was recovered.

5-Methoxy-4-nitrothionaphthen.—5-Hydroxy-4-nitrothionaphthen with an excess of diazomethane in ether gave *5-methoxy-4-nitrothionaphthen* as pale yellow needles (82%) (from ethanol), m. p. 108° (Found: C, 51·6; H, 3·3. $C_9H_7NO_3S$ requires C, 51·9; H, 2·9%).

Trinitrothionaphthens.—Attempts to nitrate 5-nitrothionaphthen-2-carboxylic acid at room temperature led to recovery of unchanged starting material. Concentrated nitric acid (1·2 ml., 0·019 mole) and concentrated sulphuric acid (9·0 ml.) were added to a solution of 5-nitrothionaphthen-2-carboxylic acid (2·1 g., 9·4 mmole) in acetic acid (30 ml.), and the solution was heated on the steam-bath for 20 min. The addition of water precipitated an orange solid partially soluble in a small amount of benzene and forming light brown crystals (1·0 g., 29%), m. p. 163°. The residue formed pale yellow needles (0·4 g., 12%), m. p. 193°, from ethanol. The infrared spectrum (Nujol) of neither compound showed carboxyl absorption; analyses were consistent with *trinitrothionaphthens* [Found: (*a*) C, 35·7; H, 1·3; N, 15·4. (*b*) C, 35·2; H, 1·0. $C_8H_3N_3O_6S$ requires C, 35·7; H, 1·1; N, 15·6%).

Methyl 5-Hydroxythionaphthen-2-carboxylate.—Excess of diazomethane (0·1 mole) in ether was added to a solution of 5-hydroxythionaphthen-2-carboxylic acid (3·51 g., 0·018 mole) in ethanol. After 24 hr. the solvent was removed under reduced pressure. The *ester* formed plates (3·60 g., 96%) (from benzene), m. p. 162—163° (Found: C, 57·9; H, 3·9. $C_{10}H_8O_3S$ requires C, 57·7; H, 3·9%).

With acetyl chloride in pyridine (20 ml.) at 5° (2 hr.) this gave the *acetyl* derivative (feathery needles) (83%; from ethanol), m. p.130° (Found: C, 57·4; H, 4·0. $C_{12}H_{10}O_4S$ requires C, 57·6; H, 4·0%).

3-Bromo-5-nitrothionaphthen-2-carboxylic Acid.—When bromine (8·0 g., 0·050 mole) was gradually added to a solution of sodium 5-nitrothionaphthen-2-carboxylate (12·0 g., 0·049 mole) in water (1 l.), a bromo-compound was precipitated (11·0 g., 73%). Efficient stirring was required to prevent the product from being contaminated by unbrominated acid. Crystallisation from ethanol gave material of m. p. 307—309° (lit.,[2] 310°) (9·6 g., 63%). (When 5-nitrothionaphthen-2-carboxylic acid was heated under reflux with bromine and sodium acetate in acetic acid it was all recovered unchanged.)

Barium 3-bromo-5-nitrothionaphthen-2-carboxylate was precipitated from a solution of the sodium salt by addition of aqueous barium chloride solution. After thorough drying the barium salt (0·50 g.) was heated with barium hydroxide (0·50 g.) at 0·5 mm. At 300° vigorous decarboxylation took place and the product obtained by ether-extraction crystallised from ethanol as pale yellow needles (0·12 g., 32%), m. p. 173° and mixed m. p. with 3-bromo-5-nitrothionaphthen 172°; infrared spectra in Nujol of the two samples were identical (Found: C, 37·3; H, 1·5. Calc. for $C_8H_4BrNO_2S$: C, 37·2; H, 1·5%).

Methyl 5-Acetamidothionaphthen-2-carboxylate.—To 5-aminothionaphthen-2-carboxylic acid (1·1 g., 5·7 mmole) in methanol (20 ml.), an excess of ethereal diazomethane (0·01 mole) was added. The solvent was allowed to evaporate overnight, and the product dissolved in pyridine (10 ml.). Acetyl chloride (0·46 g., 5·8 mmole) was added at 5°, and the *acetyl compound* precipitated by addition of water. White crystals (0·77 g., 54%) obtained from benzene–light

petroleum (b. p. 60—80°) had m. p. 151° (Found: C, 57·8; H, 4·3. $C_{12}H_{11}NO_3S$ requires C, 57·8; H, 4·5%).

Methyl 3-Bromo-5-nitrothionaphthen-2-carboxylate.—3-Bromo-5-nitrothionaphthen-2-carboxylic acid (1·9 g., 6·3 mmole) in methanol (100 ml.) with ethereal diazomethane (0·01 mole) (12 hr.) gave the *ester* (1·8 g., 91%), m. p. 211—212° (from ethanol) (Found: C, 38·3; H, 2·0. $C_{10}H_6BrNO_4S$ requires C, 38·0; H, 1·9%).

Reduction with Raney Nickel and Hydrazine Hydrate.—The preceding ester (1·2 g., 3·8 mmole) was heated in ethanol with Raney nickel (2 g.) and hydrazine hydrate (5 ml.) on the steam-bath for 30 min. The product obtained by the removal of solvent under reduced pressure was immediately dissolved in pyridine (15 ml.), and acetyl chloride (0·30 g., 3·8 mmole) was added dropwise at 5°. Addition of water precipitated methyl 5-acetamidothionaphthen-2-carboxylate (0·65 g., 69%), m. p. 151° and mixed m. p. 150—151° (from benzene–light petroleum).

2,3-Dibromo-5-nitrothionaphthen.—Sodium 3-bromo-5-nitrothionaphthen-2-carboxylate (2·4 g., 7·4 mmole) was treated in distilled water (50 ml.) with excess of silver nitrate solution. The precipitated silver salt was dried and suspended in dry carbon tetrachloride (40 ml.) containing bromine (1·18 g., 7·5 mmole), and the mixture was heated under reflux for 2 hr. The precipitated silver bromide was removed from the hot solution. 2,3-Dibromo-5-nitrothionaphthen (1·75 g., 70%) crystallised in yellow needles, m. p. 216° (lit.,[2] 217—218°).

5-Iodothionaphthen.—5-Aminothionaphthen sulphate (11·3 g., 0·057 mole) was suspended in water (1 l.) containing concentrated sulphuric acid (19·5 ml.). Sodium nitrite (4·5 g., 0·057 mole) in water (50 ml.) was added dropwise at 5° and the mixture stirred for 2 hr. The cold solution was filtered directly into one of potassium iodide (83 g., 0·5 mole) in water (500 ml.) and heated for 20 min. at 90°. Extraction with ether followed by washing of this extract with potassium iodide solution and sodium hydroxide solution yielded, on removal of ether, *5-iodothionaphthen*, colourless crystals (6·3 g., 49%), m. p. 54° (from ethanol) (Found: C, 37·1; H, 1·9. C_8H_5IS requires C, 36·9; H, 1·9%).

5,5′-Dithionaphthenylamine-2,2′-dicarboxylic Acid.—The yellow material obtained as by-product in the Bucherer reaction [2] was taken up in a minimum amount of dry pyridine, and the solution filtered through hardened filter paper. The solution was then diluted with water and acetic acid, to give *the acid*, m. p. >360°. Peaks at 1670 and 1284 cm.$^{-1}$ with broad absorption below 2800 cm.$^{-1}$ in the infrared spectrum in Nujol showed the presence of carboxylic acid functions whilst the peak at 3360 cm.$^{-1}$ indicated the secondary amine (Found: C, 58·5; H, 3·0; N, 3·8; S, 17·4. $C_{18}H_{11}NO_4S_2$ requires C, 58·6; H, 3·5; N, 3·8; S, 17·0%).

5,5′-Dithionaphthenylamine.—The foregoing acid (4·5 g.), copper bronze (8·0 g.), and quinoline (60 ml.) were heated under nitrogen at 180° for 45 min.; vigorous evolution of carbon dioxide was observed. The mixture was allowed to cool under nitrogen and diluted with ether. After removal of the copper bronze and ether, the quinoline solution was poured into 6N-sulphuric acid (600 ml.). A brown solid was precipitated; from ethanol it formed feathery needles (2·2 g., 65%), m. p. 157—158°, mixed m. p. 156° (infrared spectra of the two samples in Nujol were identical) (Found: C, 67·9; H, 3·8; N, 5·2; S, 22·7. $C_{16}H_{11}NS_2$ requires C, 68·3; H, 3·9; N, 5·0; S, 22·8%).

5,5′-Dithionaphthenylamine was prepared unambiguously by an adaptation of the method used for preparing diphenylamine.[10] 5-Aminothionaphthen (0·30 g.) and 5-aminothionaphthen hydrochloride (0·35 g.) were heated together in a sealed tube at 240° for 30 hr. The secondary amine extracted with hot ethanol formed needles (from ethanol) (0·25 g., 43%), m. p. 156°.

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