THIOPHENES AND THIAPYRANS

Part XII. Synthesis of Thiophthenes

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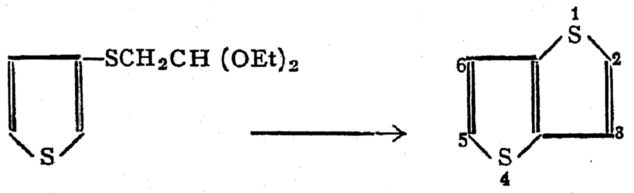
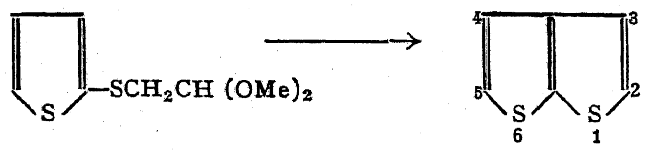
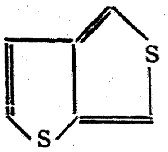
The action of acetylene on molten sulphur gives a solid and a liquid thienothiophene (thiophthenes).[1, 2] The constitution (I) of the solid isomer was assigned on the basis of physical determinations such as X-ray crystal analysis[3] and dipole moment which was zero.[4] This structure was confirmed recently by Challenger *et al.* by the synthesis of the solid thiophthene by reduction of 3-hydroxythieno(3 : 2-*b*)thiophene.[5] The liquid thiophthene was constituted as thieno(2 : 3-*b*)thiophene (II) because of its alternative synthesis from tricarballylic acid or citric acid,[6] but this synthesis would not exclude an alternative structure (III). Challenger and Emmott have recently proved the constitution of the liquid thiophthene as (II) by a study of its substitution reactions.[7] An unambiguous synthesis of (II) has not been reported in the literature so far. The structures (I) and (II) assigned to the solid and liquid thiophthenes have now been confirmed by unambiguous synthesis following the general method for the synthesis of thiophenes and thiapyrans described by us earlier.[8] A brief report of the work was published by us recently[9] and the present paper gives experimental details.



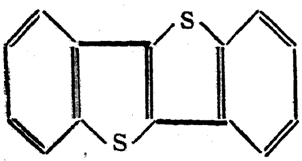
(IV) (I)



(V) (II)



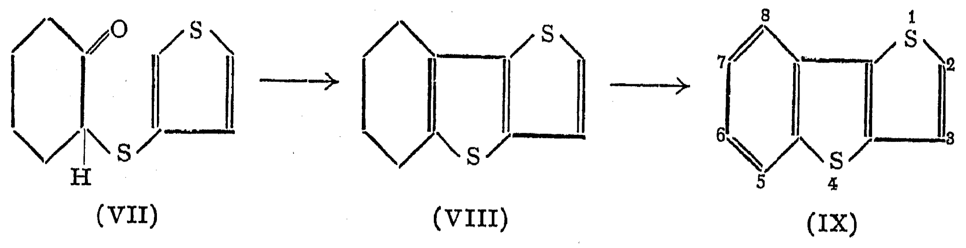
(III)



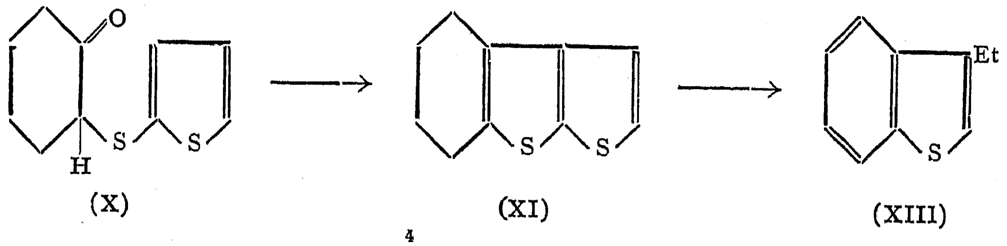
(VI)

Thieno(3 : 2-*b*)thiophene (I) was prepared starting from 3-thiophenethiol by the condensation with bromoacetaldehyde diethyl acetal, and cyclization of the resulting 3-thienyl 2 : 2-diethoxyethyl sulphide (IV). Thieno(2 : 3-*b*)-thiophene (II) was prepared similarly by the ring closure of 2-thienyl 2 : 2-dimethoxyethyl sulphide (V). The properties of (I) and (II) correspond to those of the solid and liquid thiophthenes described in the literature.

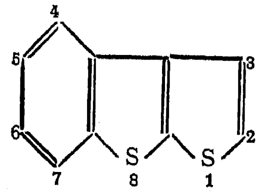
Except for thionaphtheno(3 : 2-*b*)thionaphthene (VI), prepared by the pyrolysis of *S*-acetylthiosalicylic acid[10] and by the action of phosphorus pentoxide on thiosalicylic acid,[11] other condensed ring systems containing the structures (I) or (II) are unknown. The synthesis of benzo derivatives of (I) and (II) is now reported.



(VII) (VIII) (IX)



(X) (XI) (XIII)



(XII)

Condensation of 3-thiophenethiol with 2-bromocyclohexanone gave 2-(3′-thienylmercapto)cyclohexanone (VII) which, on cyclization, gave 5 : 6 : 7 : 8-tetrahydrothieno(3 : 2-*b*)thionaphthene (VIII). Dehydrogenation of the latter with diphenyl disulphide (*cf.* Nakazaki[12]) gave thieno(3 : 2-*b*) thionaphthene (IX) with the simultaneous formation of thiophenol. 4: 5: 6: 7-Tetrahydrothieno(2 : 3-*b*)thionaphthene (XI) was prepared similarly starting from 2-thiophenethiol and 2-bromocyclohexanone through 2-(2′-thienylmercapto)-cyclohexanone (X). Attempts to convert (XI) to thieno (2 : 3-*b*)thionaphthene (XII) by dehydrogenation with usual reagents, such as sulphur, N-bromosuccinimide, diphenyl disulphide, and selenium proved unsuccessful. Treatment of (XI) with selenium at 304° gave 3-ethylthionaphthene

(XIII) instead of (XII). Further attempts to synthesise (XII) are in progress. The numbering and nomenclature of the above compounds are in accordance with Ring Index.[13]

EXPERIMENTAL

Thienyl 2:2-dialkoxyethyl sulphides were characterized as 2:4-dinitrophenylhydrazones of the parent S-thienylthioglycolic aldehydes. Thienylmercaptocyclohexanones were also characterized as 2:4-dinitrophenylhydrazones. The thiophthenes were characterized by preparation of complexes with picric acid or *sym*-trinitrobenzene. 2-Thiophenethiol was prepared according to Caeser and Branton[14] from 2-iodothiophene and 3-thiophenethiol was obtained by courtesy of Socony Vacuum Oil Company.

3-*Thienyl* 2:2-*diethoxyethyl sulphide* (*IV*)

3-Thiophenethiol (11·3 g.), sodium (2·3 g.), bromoacetaldehyde diethyl acetal (20 g.) and alcohol (50 c.c.) were refluxed for four hours. The sulphide (18·5 g.), after distillation gave a colourless oil (15 g., yield, 66%), b.p. 115–20° (bath temp.)/1 mm. (Found: C, 51·2; H, 6·8. $C_{10}H_{16}O_2S_2$ requires: C, 51·7; H, 6·9%). 2:4-*Dinitrophenylhydrazone* gave orange needles from alcohol, m.p. 113° (Found: N, 16·4. $C_{12}H_{10}N_4O_4$ requires N, 16·6%).

Thieno(3:2-*b*)*thiophene* (*I*)

The sulphide (IV) (5·0 g.) and phosphorus pentoxide (12·5 g.) were refluxed in benzene (50 c.c.) for two hours. The benzene extract was removed by decantation and the residue was extracted with more benzene. The crude product (2 ·9 g.) obtained on removal of benzene was purified through the picrate when it gave a white solid (0·55 g., yield 18%). Crystallization from *n*-hexane gave colourless flakes, m.p. 55° (Challenger *et al.*,[5] 54°) (Found: C, 51·5; H, 3·3. Calc. for $C_6H_4S_2$: C, 51·4; H, 2·9%). The *picrate* crystallized in yellow needles from alcohol, m.p. 146° (Found: C, 39·1; H, 2·0; N, 11·3. $C_{12}H_7N_3O_7S_2$ requires C, 39·0; H, 1·9; N, 11·4%).

2-*Thienyl* 2:2-*dimethoxyethyl sulphide* (*V*)

2-Thiophenethiol (12·6 g.), sodium (2·5 g.), bromoacetaldehyde dimethyl acetal (19·5 g.), and absolute alcohol (50 c.c.) were refluxed for four hours. The sulphide (19·2 g.) after distillation gave a colourless oil (16·1 g.; yield, 72·5%), b.p. 120–24° (bath temp.)/1 mm. (Found: C, 47·2; H, 6·1. $C_8H_{12}O_2S_2$ requires C, 47·1; H, 5·9%). 2:4-*Dinitrophenylhydrazone* gave yellow needles from alcohol, m.p. 115° (Found: N, 16·2. $C_{12}H_{10}N_4O_4S_2$ requires N, 16·6%).

Thieno(2 : 3-b)*thiophene* (*II*)

The sulphide (V) (1·6 g.) was refluxed with phosphorus pentoxide (7·5 g.) and phosphoric acid, sp. gr. 1·75 (10 c.c.) in dry benzene (40 c.c.). The crude thiophthene (1·5 g.), isolated as before, gave on distillation a liquid (0·5 g.) which on further purification through the picrate gave a pale yellow oil (0·2 g.), b.p. 75–80° (bath temp.)/1 mm. (Literature[1, 6] 225°, 226°) (Found C, 51·2; H, 2·8. $C_6H_4S_2$ requires C, 51·4; H, 2·9%).

The *picrate* crystallized from ethyl alcohol in yellow needles, m.p. 135–36° (Literature[1, 6] 134°, 133°) (Found: N, 11·1; $C_{12}H_7N_3O_7S_2$ requires N, 11·4%).

2-(3′-*Thienylmercapto*)*cyclohexanone* (*VII*)

A solution of 3-thiophenethiol (18 g.) in 20% aqueous sodium hydroxide (28·6 c.c.) was cooled to 20–25° and 2-bromocyclohexanone (27·4 g.) was gradually added in ten minutes under stirring and cooling. After stirring for one and half hours, the reaction mixture was diluted with water and the product (30 g.) which separated as an oil was isolated by means of ether. Attempts to purify the product by vacuum distillation were unsuccessful because of the cyclization of the product during distillation. 2 : 4-*Dinitrophenylhydrazone* gave lustrous yellow needles from alcohol, m.p. 147–48° (Found: N, 14·1; $C_{16}H_{16}N_4O_4S_2$ requires N, 14·3%).

5 : 6 : 7 : 8-*Tetrahydrothieno*(3 : 2-b)*thionaphthene* (*VIII*)

A mixture of (VII) (2·8 g.), phosphorus pentoxide (7 g.) and dry benzene (30 c.c.) was refluxed for two hours. The crude product (2·7 g.), isolated by benzene extraction, on distillation gave a pale yellow oil, b.p. 125–30° (bath temp.)/0·7 mm. (Found: C, 61·6; H, 5·3. $C_{10}H_{10}S_2$ requires C, 61·3; H, 5·1%). The *picrate* crystallized from alcohol in dark red needles m.p. 107–8° (Found: N, 9·9. $C_{16}H_{13}N_3O_7S_2$ requires N, 9·9%).

Thieno(3 : 2-b)*thionaphthene* (*IX*)

A mixture of (VIII) (2·3 g.) and diphenyldisulphide (4·6 g.) was heated in a bulb tube at 250° for one hour. Thiophenol (4 g.), which was formed as the dehydrogenation progressed, distilled over and was removed. The residue left in the bulb tube was then distilled at 160–180°/1 mm. The distilled product (1·2 g., yield 80%) gave colourless needles from alcohol, m.p. 87–88° (Found: C, 63·5; H, 3·2. $C_{10}H_{16}S_2$ requires C, 63·2; H, 3·2%). The *sym-trinitrobenzene derivative* crystallized from alcohol in yellow needles, m.p. 135°. (Found: C, 47·7; H, 2·1; N, 10·4. $C_{16}H_9N_3O_6S_2$ requires C, 47·5; H, 2·2; N, 10·4%).

2-(2′-*Thienylmercapto*)*cyclohexanone* (*X*)

A solution of 2-thiophenethiol (14·2 g.) in 20% aqueous sodium hydroxide (25 c.c.) (1 mol.) was cooled to 20–25° and 2-bromocyclohexanone (21·4 g.) was gradually added in 15 minutes under stirring and cooling. After stirring for one and half hours, the mixture was extracted with ether. The product (21 g.), obtained after removal of ether, crystallized from petroleum ether in colourless needles, m.p. 60° (15 g., yield 81%) (Found: C, 56·5; H, 5·6. $C_{10}H_{12}OS_2$ requires C, 56·6; H, 5·6%). 2:4-*Dinitrophenylhydrazone* crystallized from alcohol in yellow needles, m.p. 183–4° (Found: C, 48·5; H, 4·3; N, 14·3. $C_{16}H_{16}N_4O_4S_2$ requires C, 48·8; H, 4·1; N, 14·3%).

4:5:6:7-*Tetrahydrothieno*(2:3-b)*thionaphthene* (*XI*)

A mixture of (X) (1 g.) and phosphorus pentoxide (2 g.) was heated in an oil-bath at 160–70° for 30 minutes. The crude product (0·5 g.), isolated by benzene extraction, gave on distillation a colourless liquid (0·4 g., yield 44%), b.p. 130–40°/1 mm. (Found: C, 62·0; H, 5·1. $C_{10}H_{10}S_2$ requires C, 61·9; H, 5·1%). The *sym-trinitrobenzene derivative* gave golden yellow needles from alcohol, m.p. 106–7° (Found: C, 47·1; H, 3·2; N, 10·3. $C_{16}H_{13}N_3O_6S_2$ requires C, 47·2; H, 3·2; N, 10·1%).

Attempts to dehydrogenate (*XI*)

A mixture of (XI) (1·1 g.) and selenium (1·1 g.) was heated in a test tube fitted with an air condenser at 304° for 12 hours. The reaction product (1·1 g.), isolated by extraction with *n*-hexane, gave on distillation a colourless liquid (0·6 g.), b.p. 80–90°/1 mm., which analyses correctly for 3-ethylthionaphthene (XIII) (Buu-Hoï and Cagniant,[15] b.p. 180°/83 mm.) (Found: C, 74·5; H, 6·0. Calc. for $C_{10}H_{10}S$: C, 74·1; H, 6·1%). The picrate crystallizes from alcohol in orange plates, m.p. 78° (Buu-Hoï and Cagniant,[15] m.p. 78°).

Attempts to dehydrogenate (XI) by treatment with sulphur, N-bromosuccinimide, chloranil, diphenyl disulphide were also unsuccessful.

SUMMARY

Thieno(3:2-*b*)thiophene (I) and thieno(2:3-*b*)thiophene (II) were prepared starting from 3- and 2-thiophenethiols and bromoacetaldehyde dialkoxy acetals. Condensation of the latter with the thiols gave 3-thienyl 2:2-diethoxyethyl sulphide (IV) and 2-thienyl 2:2-dimethoxyethyl sulphide (V) which on cyclization gave (I) and (II).

Thieno(3 : 2-*b*)thionaphthene (IX) was prepared starting from 3-thiophenethiol and 2-bromocyclohexanone. Condensation of the latter compounds gave 2-(3′-thienylmercapto)cyclohexanone which on cyclization gave 5 : 6 : 7 : 8-tetrahydro-thieno(3 : 2-*b*)thionaphthene (VIII). Dehydrogenation of (VIII) gave (IX). 4 : 5 : 6 : 7-Tetrahydrothieno(2 : 3-*b*)thionaphthene (XI) was prepared similarly starting from 2-thiophenethiol. Attempts to dehydrogenate (XI) to thieno (2 : 3-*b*) thionaphthene (XII) were unsuccessful.

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