374. *The Formation and Fission of Quaternary Salts of Heterocyclic Bases containing Reactive Alkylthio-groups.*

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A detailed study has been made of the formation of quaternary salts by the action of methyl and ethyl iodides on 2-methylthio- and 2-ethylthio-benzothiazole, -benzoxazole, -pyridine, and -quinoline and the isomeric thiones. The reactions of methyl and ethyl toluene-*p*-sulphonates with the benzothiazole and quinoline compounds are also described. Contrary to published statements (Beilenson and Hamer, *J.*, 1939, 148: Sexton, *ibid.*, p. 470) the anomalous quaternisations previously observed for certain of these reactions lead, not to single compounds, but to a mixture of quaternary salts. A mechanism for these anomalous quaternisations is postulated and additional anomalies are described. Attention is drawn to the two-fold reactivity shown by the 2-alkylthio-group in the quaternary salts.

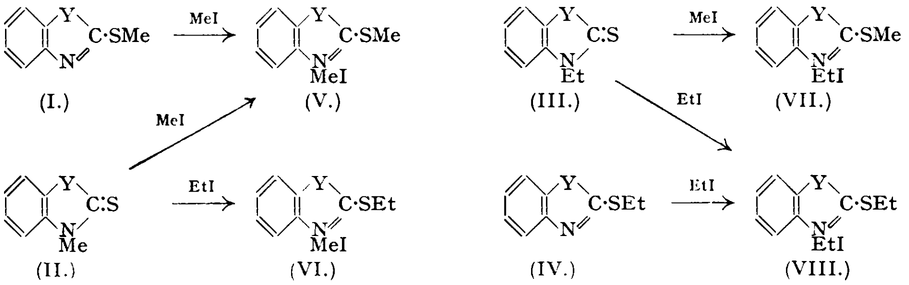
Beilenson and Hamer (*J.*, 1939, 148) reported that, whilst the action of ethyl iodide on 2-methylthiobenzothiazole (I; Y = S) gave 2-methylthiobenzothiazole ethiodide (VII; Y = S), that of ethyl iodide on 2-methylthioquinoline (I; Y = CH:CH) gave 2-ethylthioquinoline methiodide (VI; Y = CH:CH). Sexton (*J.*, 1939, 470) stated that anomalous quaternisation also occurred in the first reaction, 2-ethylthiobenzothiazole methiodide (VI; Y = S) being formed. No mechanism for the observed interchanges was postulated by these authors, but Davies and Sexton (*J.*, 1942, 304) and Mann and Watson (*J. Org. Chem.*, 1948, **13**, 502), suggested that the reaction of an alkyl iodide on a 2-alkylthiobenzothiazole involved an initial sulphonium salt formation followed by a rearrangement to the quaternary ammonium salt obtained.

In order to elucidate the mechanism of the apparent interchange of groups on the sulphur and the nitrogen atoms in the above quaternisations, a detailed examination was made of the action of methyl and ethyl iodides on 2-methylthio- and 2-ethylthio-benzothiazole (IV; Y = S), and on the analogous quinoline compounds (I and IV; Y = CH:CH) and the isomeric thiones (II and III) which also add alkyl iodides to give salts. For reasons associated with their colours and reactions, we regard the salts, whether formed from the thioethers or from the thiones, as quaternary ammonium and not sulphonium compounds as suggested by Fischer (*Ber.*, 1902, **35**, 3677) and I. G. Farbenind. A.G. (B.P. 423,492). We believe also that such ammonium compounds are the initial products of quaternisations, even with thiones, the dipolar form of the latter (see Oesper, Lewis, and Smyth, *J. Amer. Chem. Soc.*, 1942, **64**, 1131) activating the alkyl iodide to give a positively charged alkyl radical, which attaches itself to the negatively charged sulphur of the thione, and a negatively charged halide ion which becomes associated with the nitrogen atom.

As detailed below our experiments show that when a heterocyclic 2-alkylthio-base or the isomeric thione is quaternised with an alkyl iodide, containing the same alkyl group, single compounds are obtained and these are identical. In the case of a thione and an alkyl salt with an alkyl group different from that of the thione, only one compound is formed too, so that from (II) and (III), with methyl and ethyl iodide, four pure quaternary salts (V), (VI), (VII), and (VIII), can be prepared. The action of an alkyl iodide on a 2-alkylthiobenzothiazole or a 2-alkylthioquinoline with an alkyl group different from that of the alkyl iodide can, however, lead to a mixture of quaternary salts, the formation of which is nevertheless capable of a simple explanation.

If, as we believe, the initial reaction between an alkyl halide and a 2-alkylthio-base is a simple quaternisation of the nitrogen atom, then when 2-methylthiobenzothiazole (I; Y = S) is heated with ethyl iodide some 2-methylthiobenzothiazole ethiodide (VII; Y = S) is formed. If this salt were stable under the conditions of the reaction or underwent fission in the same way as 2-methylthiopyridine methiodide on being heated (Fischer, *loc. cit.*), (VII; Y = S) would be the only salt isolated from the reaction mixture. Quaternary salts of 2-alkylthiobenzothiazoles, however, on being heated with weak organic bases very easily give thiones (Kendall, B.P. 475,647). The salt (VII; Y = S), therefore, when heated with the large quantity of (I; Y = S), initially present, undergoes fission to give (III; Y = S) and (V; Y = S). The thione (III; Y = S) then reacts with ethyl iodide, which is also present in considerable quantity at the beginning of the reaction, to give 2-ethylthiobenzothiazole ethiodide (VIII; Y = S). Both quaternary salts are again dequaternised by 2-methylthiobenzothiazole to give the thiones (II and III; Y = S) and the salts (V; Y = S) and (VII; Y = S). In this way it is possible to obtain from 2-methylthiobenzothiazole and ethyl iodide a mixture of four different quaternary salts and not merely 2-ethylthiobenzothiazole methiodide as reported by Sexton (*loc. cit.*). Since, however, (V; Y = S) and (VI; Y = S) are the least soluble, crystallisation of the mixed salts normally gives a mixture of the two methiodides. In many cases, after repeated recrystallisations, only (V; Y = S) is isolated. The quaternary salts obtained by addition of ether to the filtrates after crystallisation are still a mixture and possess a very low melting point. Although it is almost certain that this mixture contains (VII and VIII; Y = S), their isolation is difficult since they are not very stable and are decomposed on repeated crystallisation. Experimental evidence below on the action of small quantities of alkyl iodides on 2-alkylthiobenzothiazoles supports this mechanism of the formation of a mixture.

When 2-ethylthiobenzothiazole (IV; Y = S) is heated with methyl iodide, 2-methylthiobenzothiazole methiodide is again formed by a series of reactions similar to those described above and is isolated as the least soluble product after crystallisation. Since, however, there is no change in the group attached to the nitrogen atom, no anomalous salt formation is evident when the quaternary salt is used for cyanine dye condensations. As a general principle we believe, nevertheless, that it is inadvisable to attempt the preparations of pure thiacyanine dyes from alkiodides obtained by the action of ethyl or methyl iodide on a 2-alkylthiobenzothiazole in which the alkyl group is different from that of the alkiodide employed.



The quaternary alkiodides of 2-alkylthioquinolines are higher melting and more stable than 2-alkylthiobenzothiazole alkiodides. The former, for example, can be crystallised from alcohols without marked decomposition. Although converted by boiling pyridine into thiones, the 2-alkylthioquinoline alkiodides do not invariably undergo a similar conversion when heated at 100° with 2-alkylthioquinolines. Thus, when 2-ethylthioquinoline (IV; Y = CH:CH) is heated with a small quantity of methyl iodide no thione can be detected, only 2-ethylthioquinoline methiodide (VI; Y = CH:CH) and unchanged thioether being isolated from the reaction mixture. 2-Methylthioquinoline (I; Y = CH:CH), on the other hand, when heated with a small quantity of ethyl iodide, gives a mixture containing (II, V, and VI; Y = CH:CH) and unchanged thioether. The reaction of 2-ethylthioquinoline with methyl iodide (Beilenson and Hamer, *loc. cit.*) results therefore in a straightforward quaternisation, whilst the action of ethyl iodide on 2-methylthioquinoline gives an anomalous quaternisation.

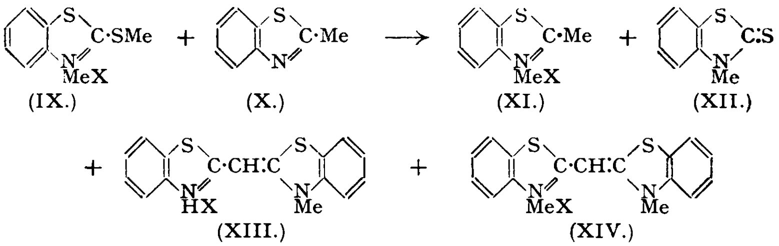
Although the melting points of 2-alkylthio-benzothiazole and -quinoline alkiodides are an aid to identification, it is found that in certain cases mixed melting points are unreliable. Thus as Sexton (*loc. cit.*) reported, no depression is obtained on admixture of compounds assumed from their reactions to be 2-methylthiobenzothiazole ethiodide and 2-ethylthiobenzothiazole methiodide. The identification of a quaternary 2-alkylthio-salt can, however, be made by converting it, by means of sodium sulphide, into a thione and an alkanethiol (cf. Sexton, *loc. cit.*) which can be identified as a mercury mercaptide. The method also serves to demonstrate the presence of a mixture of quaternary salts and, in some cases, to identify its components.

The preparation of cyanine dyes by the fusion process of Kendall (B.P. 438,420) using alkyl toluene-*p*-sulphonates of 2-methylthio- and 2-ethylthio-benzothiazole, and the corresponding quinoline compounds, results in the formation of dyes which would be expected if the quaternisations proceeded normally, suggesting that these salts are more stable than the alkiodides. This was confirmed by preparation of the alkyl toluene-*p*-sulphonates from both 2-alkylthio-bases and the appropriate thiones, using molecular proportions of the reactants. When, however, 2-ethylthiobenzothiazole was heated with an excess of methyl toluene-*p*-sulphonate a mixture was obtained from which 2-methylthiobenzothiazole methotoluene-*p*-sulphonate was isolated.

The increased stability of 2-alkylthioquinoline alkyltoluene-*p*-sulphonates, compared with the corresponding alkiodides, was confirmed by the fact that the former, unlike the latter, are not converted into thiones on being heated with pyridine.

For comparative purposes, a study was made of the action of methyl and ethyl iodides on 2-alkylthio-pyridines and -benzoxazoles and their isomeric thiones. 2-Alkylthiopyridines, when heated with alkiodides, invariably give quaternary salts without any group interchange. No quaternary alkiodides could be isolated from 2-alkylthiobenzoxazoles or the isomeric thiones, the salts formed initially undergoing immediate fission to a thione and an alkyl iodide. Although the action of alkyl toluene-*p*-sulphonates on 2-alkylthiobenzoxazoles or the isomeric thiones gives solid quaternary salts, these are too unstable for purification. They can, however, be used in the preparation of oxacyanine dyes as described by Kendall (*loc. cit.*).

The structures of the alkyl salts of heterocyclic 2-alkylthio-bases, as exemplified by their reactions, are of interest. 2-Alkylthiobenzothiazole salts, in the presence of a weak base, readily give rise to thiones with fission of the bond linking the sulphur and the alkyl group of the thioether grouping. In the presence of strong bases, in hydroxylic solvents, fission occurs most readily at the bond linking the sulphur atom of the thioether grouping with the carbon atom of the thiazole ring (Sexton, *loc. cit.*). The normal reaction between a thioether quaternary salt and a compound containing a reactive methylene group also involves the breaking of the bond linking the sulphur of the thioether group and the carbon atom of the heterocyclic ring. When a 2-methylthiobenzothiazole alkyl salt (IX) and 2-methylbenzothiazole (X) are heated together fissions of both types occur. The extent to which one or other type takes place, however, varies with the alkyl salt. 2-Methylbenzothiazole and (IX; X = I), for example, give excellent yields of (XI; X = I) and the thione (XII) together with traces of a yellow dye, possibly (XIII or XIV; X = I). The salt (IX; $X = C_7H_7{\cdot}SO_3$) and (X), on the other hand, give mainly the toluene-*p*-sulphonate of the thiacyanine base (cf. XIII) and minute quantities of (XI; $X = C_7H_7{\cdot}SO_3$), (XII), and the thiacyanine dye (XIV; $X = C_7H_7{\cdot}SO_3$).



(IX.) (X.) (XI.) (XII.) (XIII.) (XIV.)

EXPERIMENTAL.

All reactions with alkyl iodides were carried out at atmospheric pressure on the water-bath and products freed from basic compounds by extraction with benzene and/or acetone.

2-*Methylthiobenzothiazole Methiodide*.—This was obtained (85%) from 2-methylthiobenzothiazole and excess of methyl iodide (48 hours' heating), or from the latter and 2 : 3-dihydro-3-methylbenzothiazole-2-thione (1 hour). It formed long colourless needles, m. p. 148° (decomp.), from ethanol (50 c.c. per g.) (Found : S, 20·25; I, 39·45. Calc. for $C_9H_{10}NIS_2$: S, 19·85; I, 39·25%). Beilenson and Hamer (*loc. cit.*) give m. p. 146° (decomp.). Rassow, Döhle, and Reim (*J. prakt. Chem.*, 1916, **93**, 204) give m. p. 139°.

2-*Ethylthiobenzothiazole Methiodide*.—This was obtained (75%) from 2 : 3-dihydro-3-methylbenzothiazole-2-thione and ethyl iodide (8 hours' heating) and formed colourless prismatic needles, m. p. 140° (decomp.), from ethanol (7 c.c. per g.) (Found : S, 18·7; I, 37·35. Calc. for $C_{10}H_{12}NIS_2$: S, 19·0; I, 37·65%). Rassow *et al.* (*loc. cit.*) give m. p. 132°; Sexton (*loc. cit.*) gives m. p. 140°.

2-*Methylthiobenzothiazole Ethiodide*.—Prepared (95%) from 3-ethyl-2 : 3-dihydrobenzothiazole-2-thione and methyl iodide (4 hours' heating), this *salt* formed colourless prismatic needles, m. p. 136° (decomp.), from methanol (5 c.c. per g.) (Found: C, 35·3; H, 3·75; S, 19·25. $C_{10}H_{12}NIS_2$ requires C, 35·6; H, 3·6; S, 19·0%). Sexton (*loc. cit.*) gives m. p. 131° but no analytical data.

2-*Ethylthiobenzothiazole Ethiodide*.—This was obtained [90%; m. p. 116° (decomp.)] from 3-ethyl-2 : 3-dihydrobenzothiazole-2-thione and ethyl iodide (4 hours' heating) or (3%) from the latter and 2-ethylthiobenzothiazole (15 hours' heating) (Found : I, 36·4. Calc. for $C_{11}H_{14}NIS_2$: I, 36·15%). 2-Ethylthiobenzothiazole ethiodide is hygroscopic and unless stored *in vacuo* increases in weight, whilst the m. p. drops. A similar drop in m. p. also occurs when the compound is recrystallised from methanol. Brooker, White, Keyes, Smyth, and Oesper (*J. Amer. Chem. Soc.*, 1941, **63**, 3200) give m. p. 115—117°. Beilenson and Hamer (*loc. cit.*) give 95—96°.

Action of Ethyl Iodide on 2-Methylthiobenzothiazole.—2-Methylthiobenzothiazole (5·4 g., 1 mol.) and pure dry ethyl iodide (3 c.c., 1·2 mols.) were heated together (24 hours). The crude product after extraction gave a pale yellow powder (4·84 g.), m. p. 105—110° (decomp.) (Found : C, 35·45; H, 3·9; S, 19·1; I, 36·75. Calc. for $C_9H_{10}NIS_2$: C, 33·45; H, 3·1; S, 19·85; I, 39·25. Calc. for $C_{10}H_{12}NIS_2$: C, 35·6; H, 3·6; S, 19·0; I, 37·65. Calc. for $C_{11}H_{14}NIS_2$: C, 37·6; S, 19·25; I, 36·15%).

A portion (2·5 g.) of the crude quaternary salt in water (30 c.c.) was treated at 60° with a 25% (w/v) aqueous solution (12 c.c.) of crystalline sodium sulphide, and the evolved thiol aspirated (30 minutes) through 5% (w/v) aqueous mercuric cyanide (50 c.c.), giving an oily mercury derivative which was boiled with methanol (3 × 40 c.c.). The residue (0·025 g.) had m. p. 80—160°, and the solution, on cooling, also deposited a mixture of the mercury derivatives of methane- and ethane-thiol as colourless plates (0·075 g.), m. p. 90—120°, which were filtered off. This filtrate was concentrated to 25 c.c., and an equal volume of water added to give the impure mercury derivative (0·1 g.), m. p. 62—69°, of ethanethiol. The mercury derivative of methanethiol obtained from the decomposition of (V) had m. p. 172° (Klason, *Ber.*, 1887, **20**, 3410, gives m. p. 175°) and was soluble in *ca.* 100 volumes of boiling methanol, whilst that of ethanethiol from (VIII) had m. p. 74—75° (Klason, *J. pr. Chem.*, 1877, **15**, 205, gives m. p. 76—77°) and was readily soluble.

The thione (0·77 g.) obtained in the decomposition did not solidify and was dissolved in hot methanol (10 c.c.) from which, on cooling, 2 : 3-dihydro-3-methylbenzothiazole-2-thione (0·33 g.), m. p. 88—89°, was obtained. The filtrate from the thione was concentrated to 3 c.c., giving a solid (0·16 g.), m. p. 52—57°. This m. p. was raised by admixture with both 2 : 3-dihydro-3-methyl- and 3-ethyl-2 : 3-dihydro-benzothiazole-2-thione, indicating that the solid was a mixture of the two thiones.

The remainder of the crude quaternary salts (2·25 g.) was boiled with a mixture of acetone (10 c.c.) and ethanol (20 c.c.) and filtered from a little undissolved 2-methylthiobenzothiazole methiodide (0·12 g.), m. p. 146° (decomp.). On cooling, colourless needles (0·35 g.), m. p. 142° (decomp.), separated. The m. p. was raised by admixture with 2-methylthiobenzothiazole methiodide and depressed with 2-ethylthiobenzothiazole methiodide. After filtration, addition of dry ether (50 c.c.) precipitated a solid (0·67 g.), m. p. 94—96° (decomp.), depressed by admixture with 2-ethylthiobenzothiazole ethiodide and raised by admixture with 2-ethylthiobenzothiazole methiodide.

Addition of more dry ether (65 c.c.) to the filtrate from the above solid precipitated a buff-coloured solid (0·35 g.), m. p. 96—98° (decomp.) elevated by admixture with 2-ethylthiobenzothiazole ethiodide. A portion (0·2 g.) of this solid was treated with aqueous sodium sulphide, and the oily mercury derivative was boiled with methanol and decanted from a trace of the mercury derivative, m. p. 170—172°, of methanethiol. The solution, on cooling, deposited colourless plates of the mercury derivative, m. p. 70—72°, of ethanethiol. The thione obtained (0·09 g.) had m. p. 42—55° which was elevated by admixture with both the methyl and the ethyl thione. Recrystallisation from 50% aqueous methanol still gave a mixture (0·04 g.), m. p. 50—60°.

Repetition of the above reaction using ethyl iodide containing a trace of iodine which, according to Sexton (*loc. cit.*), catalyses the conversion of 2-methylthiobenzothiazole into the isomeric thione, gave substantially the same result, as did the use of twice the quantity of ethyl iodide.

Action of Methyl Iodide on 2-Ethylthiobenzothiazole.—2-Ethylthiobenzothiazole (5·0 g., 1 mol.) and methyl iodide (2·0 c.c., 1·2 mols.) were heated together for 24 hours. The product after extraction (benzene and acetone) gave a white powder (3·08 g.), m. p. 131° (decomp.), which (0·25 g. in 3 c.c. of water) with sodium sulphide gave a mixture, m. p. 128—132°, of the mercury derivatives of methane- and a little ethane-thiol. The crude quaternary salt, on crystallisation from ethanol, gave 2-methylthiobenzothiazole methiodide, m. p. 147° (decomp.) alone or mixed with the authentic compound.

Action of Ethyl Iodide on 2-Methylthiobenzothiazole Methiodide.—2-Methylthiobenzothiazole methiodide (1 g.) and ethyl iodide (5 c.c.) were boiled together (40 hours). The product (0·96 g.) had m. p. 140° (decomp.) and gave no depression admixed with either 2-methylthiobenzothiazole methiodide or 2-ethylthiobenzothiazole methiodide. A portion of the solid when treated with aqueous sodium sulphide gave 2 : 3-dihydro-3-methylbenzothiazole-2-thione and an oily thiol derivative from which the mercury derivatives of methane- and ethane-thiol were isolated. The reaction product consisted mainly, therefore, of a mixture of the methiodides of 2-methylthio- and 2-ethylthio-benzothiazole.

Reaction of 2-Methylthiobenzothiazole with a Small Quantity of Methyl Iodide.—2-Methylthiobenzothiazole (10 g.) was warmed (24 hours) with methyl iodide (0·6 c.c.). The solid product was separated by hot benzene (100 c.c.) into 2-methylthiobenzothiazole methiodide (2·23 g.) and a mixture of 2 : 3-dihydro-3-methylbenzothiazole-2-thione (5·41 g.) insoluble in concentrated hydrochloric acid, and acid-soluble 2-methylthiobenzothiazole (0·67 g.).

Reaction of 2-Methylthiobenzothiazole with a Small Quantity of Ethyl Iodide.—2-Methylthiobenzothiazole (10 g.) was warmed (24 hours) with ethyl iodide (0·78 c.c.). The product was identified as a mixture of 2-methylthiobenzothiazole methiodide (2·03 g.), 3-methyl-thione (4·57 g.), 3-ethyl-thione (1·08 g.), and unchanged thioether (1·4 g.).

Reaction of 2-Methylthiobenzothiazole Methiodide with 2-Methylthiobenzothiazole.—2-Methylthiobenzothiazole (10 g.) was warmed (24 hours) with 2-methylthiobenzothiazole methiodide (2 g.) on the water-bath. The product was identified as 2 : 3-dihydro-3-methylbenzothiazole-2-thione (5·5 g.) and unchanged 2-methylthiobenzothiazole (2 g.) and its methiodide (1·65 g.).

Reaction of 2-Ethylthiobenzothiazole with a Small Quantity of Methyl Iodide.—2-Ethylthiobenzothiazole (10 g.) was warmed (24 hours) with methyl iodide (0·65 c.c.). The oily product was diluted with benzene (100 c.c.) and decanted from insoluble oily quaternary compounds which, after recrystallisation, had m. p. 126° (decomp.). The benzene solution contained unchanged thioether (4·9 g.) together with a mixture (1·77 g.) consisting mainly of the 3-ethyl-thione with some 3-methyl-thione.

2-*Methylthiobenzothiazole Methotoluene*-p-*sulphonates*.—2-Methylthiobenzothiazole (5 g., 1 mol.) was heated with methyl toluene-*p*-sulphonate (5·14 g., 1 mol.) at 140° for 4 hours. The product, which solidified on cooling, was washed well with dry acetone to give fine colourless hygroscopic crystals (7·5 g., 74%) which softened at 162° and melted at 167°. The compound, immediately after drying, had m. p. 173°. Beilenson and Hamer (*loc. cit.*) give m. p. 167—168° with previous softening.

The same product (8·9 g., 88%), m. p. 173°, was also obtained from 2 : 3-dihydro-3-methylbenzothiazole-2-thione and methyl toluene-*p*-sulphonate on a water-bath (6 hours).

2-*Methylthiobenzothiazole Ethotoluene*-p-*sulphonate*.—This *salt* was obtained (7·95 g., 81%) similarly from 3-ethyl-2 : 3-dihydrobenzothiazole-2-thione (5 g.) and methyl toluene-*p*-sulphonate (4·77 g.) or (5·7 g., 55%) from 2-methylthiobenzothiazole (5 g.) and ethyl toluene-*p*-sulphonate (5·53 g.). It recrystallised from ethanol–acetone–ether as small colourless irregular hygroscopic plates, m. p. 154—156° (Found : S, 24·9. $C_{17}H_{19}O_3NS_3$ requires S, 25·2%).

2-*Ethylthiobenzothiazole ethotoluene*-p-*sulphonate* was obtained (3·9 g., 39%; m. p. 124°) similarly from 2-ethylthiobenzothiazole or from 3-ethyl-2 : 3-dihydrobenzothiazole-2-thione (5 g.) and ethyl toluene-*p*-sulphonate (5·13 g.). Recrystallisation from ethanol–acetone–ether gave the compound as clusters of small hygroscopic plates (2·5 g.), m. p. 125° (Found : S, 24·35. $C_{18}H_{21}O_3NS_3$ requires S, 24·30%).

2-*Ethylthiobenzothiazole methotoluene*-p-*sulphonate* was obtained (4·8 g., 48%) similarly from 2 : 3-dihydro-3-methylbenzothiazole-2-thione (5 g., 1 mol.) and ethyl toluene-*p*-sulphonate (5·53 g., 1 mol.) or (0·9 g., 9·5%) from 2-ethylthiobenzothiazole (5 g., 1 mol.) and methyl toluene-*p*-sulphonate (4·77 g., 1 mol.). The compound, which was hygroscopic, was recrystallised from dry methanol–ether to give fine colourless crystals, m. p. unsharp to 112°. After being dried to constant weight at 70° it had m. p. 140° with softening from 136° (Found : C, 53·75; H, 5·1; S, 25·2. $C_{17}H_{19}O_3NS_3$ requires C, 53·5; H, 5·0; S, 25·2%).

Action of an Excess of Methyl Toluene-p-*sulphonate on* 2-*Ethylthiobenzothiazole*.—2-Ethylthiobenzothiazole (5 g., 1 mol.) was heated with methyl toluene-*p*-sulphonate (9·54 g., 2 mols.) at 140° for 3 hours. The sticky product was washed with acetone and recrystallised from ethanol–acetone–ether to give colourless crystals (3·75 g.), m. p. 167°, alone or admixed with 2-methylthiobenzothiazole methotoluene-*p*-sulphonate (Found : C, 52·65; H, 4·56; S, 26·5. Calc. for $C_{16}H_{17}O_3NS_3$: C, 52·3; H, 4·65; S, 26·2%).

Action of a Small Quantity of Methyl Toluene-p-*sulphonate on* 2-*Methylthiobenzothiazole*.—2-Methylthiobenzothiazole (10 g.) and methyl toluene-*p*-sulphonate (1·5 g.) were heated together (24 hours) at 100°. The product was identified as 2-methylthiobenzothiazole methotoluene-*p*-sulphonate (2·74 g., 94%) and unchanged 2-methylthiobenzothiazole (6·5 g.). No thione was detected.

1 : 2-*Dihydro*-1-*methylquinoline*-2-*thione*.—2-Iodoquinoline methiodide (57 g.) was added gradually with stirring to a solution of potassium hydrogen sulphide prepared from potassium hydroxide (20 g.) in ethanol (100 c.c.). The mixture, which became warm, was boiled under reflux for 1 hour, then poured into cold water (1 l.), and the solid, which separated, was filtered off and recrystallised, without drying, from ethanol (120 c.c.). The product, long yellow needles (22·8 g., 91%), m. p. 116°, was identical with that obtained by Gutbier's method (*Ber.*, 1900, **33**, 3359; who gives m. p. 118°). The picrate, which is much more soluble than that (m. p. 185—187°) of the corresponding thioether, was obtained from the thione (0·2 g.) in ethanol (2·5 c.c.) as stout orange rhombs (0·22 g.), m. p. 104—105°. McNeil and Cowper (*J.*, 1939, 1860) give for the thioether picrate, m. p. 183—184°, and for the thione picrate, m. p. 104°.

1-*Ethyl*-1 : 2-*dihydroquinoline*-2-*thione* was obtained similarly from 2-iodoquinoline ethiodide (53 g.) and potassium hydrogen sulphide prepared from potassium hydroxide (20·4 g.) in ethanol (102 c.c.). Recrystallisation from ethanol (50 c.c.) gave yellow prisms (22 g., 91%), m. p. 59—60° (Found : S, 16·6. $C_{11}H_{11}NS$ requires S, 16·95%).

2-*Methylthioquinoline Methiodide*.—This was obtained (3·2 g., 80%) from 1 : 2-dihydro-1-methylquinoline-2-thione (2·22 g.) and methyl iodide (1 c.c.) (7 hours' heating) or (7·25 g., 77%) from the latter (3 c.c.) and 2-methylthioquinoline (5 g.) (40 hours' heating). It recrystallised from ethanol as fine yellow plates, m. p. 195° (decomp.) (Found : I, 40·05. Calc. for $C_{11}H_{12}NIS$: I, 40·0%). Beilenson and Hamer (*loc. cit.*) give m. p. 193°. When boiled with dry pyridine (10 c.c.) for 1½ hours it gave 1 : 2-dihydro-1-methylquinoline-2-thione (0·43 g., 78%). The latter, together with methanethiol, was also obtained when the quaternary salt was treated with sodium sulphide.

2-*Ethylthioquinoline Methiodide*.—This was obtained (3·15 g., 83%) from 1 : 2-dihydroquinoline-1-methyl-2-thione (2 g.) and ethyl iodide (1·5 c.c.) (7 hours' heating), or (40 hours' heating) from methyl iodide and 2-ethylthioquinoline [*picrate*, yellow prisms, m. p. 150—152° (Found : S, 7·5. $C_{11}H_{11}NS,C_6H_3O_7N$ requires S, 7·65%)]. It crystallised from ethanol (60 c.c.) as minute yellow hexagonal and rectangular plates (2·55 g.), m. p. 187° (decomp.) (Found : I, 38·15. Calc. for $C_{12}H_{14}NIS$: I, 38·3%). Beilenson and Hamer (*loc. cit.*) give m. p. 185° (decomp.). When boiled with dry pyridine (10 c.c.), the salt (1 g.) gave 1 : 2-dihydro-1-methylquinoline-2-thione (0·35 g., 66%).

2-*Methylthioquinoline ethiodide* (3·5 g., 80%), m. p. 184—186° (decomp.), was prepared similarly (1 hour's heating) from 1-ethyl-1 : 2-dihydroquinoline-2-thione (2·5 g.) and methyl iodide (1·5 c.c.). Recrystallisation from ethanol (100 c.c.) gave very fine yellow plates (2·8 g.), m. p. 185° (decomp.) (Found : I, 38·1. $C_{12}H_{14}NIS$ requires I, 38·3%). With boiling dry pyridine (10 c.c.) as described above, the salt (1 g.) gave 1-ethyl-1 : 2-dihydroquinoline-2-thione (0·45 g., 79%).

2-*Ethylthioquinoline Ethiodide*.—This was obtained (0·9 g., 99%) from 1-ethyl-1 : 2-dihydroquinoline-2-thione (0·5 g.) and ethyl iodide (0·4 c.c.) (30 minutes' heating) or (2·4 g., 27%) from the latter (3·5 c.c.) and 2-ethylthioquinoline (5 g.) (40 hours' heating). It crystallised from alcohol (50 c.c.) as fine yellow plates (1 g.). m. p. 165° (decomp.) (Found : I, 36·45. Calc. for $C_{13}H_{16}NIS$: I, 36·75%). With boiling dry pyridine (10 c.c.), the ethiodide (1 g.) gave 1-ethyl-1 : 2-dihydroquinoline-2-thione (0·35 g., 65%).

Reaction of Ethyl Iodide with 2-*Methylthioquinoline*.—2-Methylthioquinoline (5 g., 1 mol.) and ethyl iodide (2·5 c.c., 1·1 mols.) were heated (40 hours) at 100°. The yellow product, after extraction with dry acetone (20 c.c.) and ether, gave a yellow powder (5·86 g.), m. p. 163—176° (decomp.). The crude quaternary salt, after two recrystallisations from ethanol, gave fine deep yellow plates, m. p. 184° (decomp.) (Found : C, 43·55; H, 4·35; S, 9·8. Calc. for $C_{12}H_{14}NIS$: C, 43·5; H, 4·25; S, 9·7%). The m. p. was raised by admixture with 2-ethylthioquinoline methiodide, and depressed by admixture with 2-methylthioquinoline ethiodide or methiodide. A portion of the crude quaternary salt (0·5 g.) reacted with aqueous sodium sulphide (2·5 c.c.) to give an oily mercury derivative and a slightly oily thione. The latter was collected, dried (0·18 g.), and crystallised from alcohol (1 c.c.), giving yellow needles (0·10 g.), m. p. 97—99°, elevated on admixture with an authentic specimen of 1 : 2-dihydro-1-methylquinoline-2-thione. The filtrate was evaporated to dryness and the semi-solid residue stirred with a little alcohol and filtered, to give a second crop of impure thione (0·02 g.), m. p. 90—93°.

The oily mercury derivative was extracted with boiling methanol (3 × 5 c.c.), filtration being carried out after each extraction. A trace of the mercury derivative, m. p. 170—173°, of methanethiol remained undissolved. On cooling, colourless plates (0·01 g.), m. p. 90—120°, of a mixture of mercury derivatives of methane- and ethane-thiol separated from the filtrate. The filtrate on concentration gave second (0·01 g.) and third crops (0·01 g.), which were mainly the mercury derivative of ethanethiol. The original crude quaternary salts consisted, therefore, of a mixture of 2-methylthioquinoline and 2-ethylthioquinoline methiodides.

An experiment in which 2-methylthioquinoline was heated with a large excess of ethyl iodide gave similar results.

Action of a Small Quantity of Ethyl Iodide on 2-*Methylthioquinoline*.—2-Methylthioquinoline (5 g.) and ethyl iodide (0·38 c.c.) were heated together for 24 hours. The mixture was diluted with 50 c.c. of benzene and filtered from a solid (1·07 g.), m. p. 180° (decomp.), which was identified as a mixture of 2-methylthio- and 2-ethylthio-quinoline methiodides. The benzene, on evaporation, left a residue which was separated into 1 : 2-dihydro-1-methylquinoline-2-thione (1·4 g.) and unchanged thioether (1·87 g.) by dissolution in concentrated hydrochloric acid and fractional precipitation with 5% aqueous sodium carbonate.

Action of a Small Quantity of Methyl Iodide on 2-*Ethylthioquinoline*.—2-Ethylthioquinoline (5 g.) and methyl iodide (0·31 c.c.) were heated together (24 hours). The product (1·05 g.), after extraction with benzene (50 c.c.), had m. p. 182° (decomp.) and on recrystallisation from ethanol gave 2-ethylthioquinoline ethiodide (0·86 g.), m. p. 187° (decomp.) alone or admixed with the authentic compound. From the benzene solution unchanged 2-ethylthioquinoline (3·9 g.), b. p. 131—132°/3 mm., 208°/60 mm., was recovered. No thione was detected.

2-*Methylthioquinoline Methotoluene*-p-*sulphonate*.—This was obtained (10·2 g., 99%) by heating 2-methylthioquinoline or the isomeric thione (5 g.) and methyl toluene-*p*-sulphonate (5·35 g.) at 140° for 4 hours. Recrystallisation from a small volume of ethanol, containing a little acetone, gave small colourless irregular plates (6·1 g.), m. p. 159°. Beilenson and Hamer (*loc. cit.*) give m. p. 160°.

2-*Methylthioquinoline ethotoluene*-p-*sulphonate* was obtained (4·5 g., 46%) similarly from 1-ethyl-1 : 2-dihydroquinoline-2-thione (5 g.) and methyl toluene-*p*-sulphonate (4·9 g.) or (1·76 g., 17%) from 2-methylthioquinoline (5 g.) and ethyl toluene-*p*-sulphonate (5·8 g.). It recrystallised from ethanol–acetone as colourless crystals, m. p. 145° (Found : C, 60·75; H, 5·4; S, 17·0. $C_{19}H_{21}O_3NS_2$ requires C, 60·75; H, 5·65; S, 17·1%).

2-*Ethylthioquinoline methotoluene*-p-*sulphonate* was obtained (1·1 g., 86%) similarly from 1 : 2-dihydro-1-methylquinoline-2-thione (0·6 g.) and ethyl toluene-*p*-sulphonate (0·69 g.), or (9·05 g., 91%) from 2-ethylthioquinoline (5 g.) and methyl toluene-*p*-sulphonate (4·9 g.). It crystallised from ethanol–acetone as clusters of minute colourless needles, m. p. 181° (Found : S, 17·1. $C_{19}H_{21}O_3NS_2$ requires S, 17·1%).

2-Ethylthioquinoline ethotoluene-*p*-sulphonate was obtained (1·65 g., 16%) from 2-ethylthioquinoline (5 g.) and ethyl toluene-*p*-sulphonate (5·3 g.) or (2·5 g., 24%) from the latter and 1-ethyl-1 : 2-dihydroquinoline-2-thione. Recrystallisation from ethanol–acetone–ether gave colourless crystals, m. p. 128° (Found : S, 16·35. Calc. for $C_{20}H_{23}O_3NS_2$: S, 16·45%). Beilenson and Hamer (*loc. cit.*) give m. p. 116°.

2-Methylthiopyridine was prepared by the method of Marckwald, Klemm, and Trabert (*Ber.*, 1900, **33**, 1558).

2-*Ethylthiopyridine*.—2-Mercaptopyridine (22 g.) was dissolved in ethanol (50 c.c.) and a solution of sodium (4·6 g.) in ethanol (50 c.c.) added. Ethyl bromide (20 c.c.) was then added gradually and the mixture heated under reflux for 3 hours. Ethanol and excess of ethyl bromide were distilled off, and the residue cooled and diluted with water. The oil obtained was extracted with ether, washed successively with water, dilute sodium hydroxide, and water, and dried (K_2CO_3). Fractional distillation gave 2-ethylthiopyridine as an almost colourless mobile oil, b. p. 212° (Found : S, 23·0. Calc. for C_7H_9NS : S, 23·0%). Backer and Buisman (*Rec. Trav. chim.*, 1945, **64**, 102) give b. p. 205—207°.

1 : 2-Dihydro-2-methylpyridine-1-thione was prepared by the method of Michaelis and Holken (*Annalen*, 1904, **331**, 245).

1-*Ethyl*-1 : 2-*dihydropyridine*-1-*thione*.—2-Iodopyridine ethiodide (6 g.) was heated on the water-bath for 1 hour with aqueous sodium hydrogen sulphide (3 g. in 20 c.c.). The solution was cooled, extracted with ether (4 × 25 c.c.), washed with water (5 c.c.), and dried (K_2CO_3). The ether was removed and the residue (1·65 g.) crystallised from water (30 c.c.) to give 1-*ethyl*-1 : 2-*dihydropyridine*-1-*thione* as pale yellow needles, m. p. 46—48° (Found : S, 23·0. C_7H_9NS requires S, 23·0%).

2-Methylthiopyridine methiodide, m. p. 156°, was obtained as fine pale yellow needles in almost quantitiative yield from 2-methylthiopyridine and methyl iodide (3 hours' heating), or from 1 : 2-dihydro-1-methylpyridine-2-thione and methyl iodide as described by Fischer (*loc. cit.*).

2-*Ethylthiopyridine ethiodide* was obtained similarly from 2-methylthiopyridine and ethyl iodide, or from 1-ethyl-1 : 2-dihydropyridine-2-thione and methyl iodide. Recrystallisation from ethanol–ether gave the ethiodide as almost colourless flat needles, m. p. 161° (Found : I, 45·6. $C_8H_{12}NIS$ requires I, 45·2%).

2-*Ethylthiopyridine methiodide* was obtained in almost quantitative yield from 2-ethylthiopyridine and methyl iodide (6 hours' heating) as an oil which solidified on cooling and had m. p. 90—95°. Crystallisation from a small volume of ethanol gave pale yellow needles, m. p. 110° (Found : I, 45·7. $C_8H_{12}NIS$ requires I, 45·2%). The same compound separated as a solid when 1 : 2-dihydro-1-methylpyridine-2-thione was heated with ethyl iodide for 1 hour. Fischer (*loc. cit.*) using this method obtained an oil which solidified on stirring, but he gave no m. p. or analytical data.

2-*Ethylthiopyridine ethiodide* was obtained similarly from both 2-ethylthiopyridine and 1-ethyl-1 : 2-dihydropyridine-2-thione and ethyl iodide. Crystallisation from ethanol–ether gave almost colourless laths, m. p. 135° (Found : I, 43·25. $C_9H_{14}NIS$ requires I, 43·0%).

Reaction of 2-*Alkylthiobenzoxazoles with Alkyl Iodides.*—2-Methylthiobenzoxazole (3·5 g.) and methyl iodide (4·0 g.) were heated under reflux for 7 hours. The product was dissolved in hot benzene (25 c.c.), and the solution cooled, giving colourless crystals (2·64 g.), m. p. 130°, identical with 2 : 3-dihydro-3-methylbenzoxazole-2-thione. Seidel (*J. pr. Chem.*, 1890, **42**, 452) gives m. p. 128°. The benzene filtrate on evaporation left a residue (0·9 g.) of unchanged 2-methylthiobenzoxazole.

2-Ethylthiobenzoxazole (2 g.) and ethyl iodide (2 c.c.) were heated for 7 days. Recrystallisation of the product yielded unchanged thioether and 3-ethyl-2 : 3-dihydrobenzoxazole-2-thione (0·3 g., 15%), m. p. 112°. Seidel (*loc. cit.*) gives m. p. 112°.

2-Methylthiobenzoxazole (5 g.) with excess of ethyl iodide under the same conditions gave mainly unchanged thioether and a poor yield of 3-ethyl-2 : 3-dihydrobenzoxazole-2-thione (0·5 g., 9·5%), m. p. 109°.

2-Ethylthiobenzoxazole (5 g.) was heated (20 hours) with excess of methyl iodide (4·4 c.c.). The product consisted of 2 : 3-dihydro-3-methylbenzoxazole-2-thione (2·5 g.), together with unchanged starting compounds.

Action of 2-*Methylbenzothiazole on Quaternary Salts of* 2-*Methylthiobenzothiazole.*—(*a*) 2-Methylbenzothiazole (5·0 g.) and 2-methylthiobenzothiazole methiodide (2 g.) were heated together (10 hours). Benzene (20 c.c.) was added and 2-methylbenzothiazole methiodide separated (1·76 g., 98%), m. p. 218° (decomp.) alone or admixed with an authentic specimen. Repeated crystallisation from ethanol failed to remove a yellow coloration, due probably to a trace of dye. The benzene solution was evaporated and the oily residue stirred with hydrochloric acid (*d* 1·16; 7·5 c.c.), whereupon undissolved 2 : 3-dihydro-3-methylbenzothiazole-2-thione solidified and was collected (1·11 g., 98%) m. p. 85—87°.

(*b*) The above experiment was repeated using 2-methylthiobenzothiazole methotoluene-*p*-sulphonate (2 g.) instead of the methiodide. The semi-solid product was warmed with dry benzene (2 × 20 c.c.), cooled, and filtered from a yellow solid (1·83 g.), a small portion of which was tested for 2-methylbenzothiazole methotoluene-*p*-sulphonate by being heated with ethyl orthoformate and dry pyridine. A spectroscopic examination of the slightly reddish solution indicated the presence of a trace of thiacarbocyanine dye. The remainder of the solid was stirred with sodium hydrogen carbonate (0·6 g.) and water (15 c.c.); a vigorous effervescence occurred and the substance became paler. Benzene (40 c.c.) was added, whereupon most of the solid dissolved and the mixture, on filtration, left a yellow residue (0·02 g.) which was dissolved in ethanol (5 c.c.) and added to hot aqueous potassium bromide (1 g. in 10 c.c.). Bright yellow needles (0·015 g.), m. p. 285—290° (decomp.), identical with 3 : 3-dimethylthiacyanine bromide, were deposited. The benzene solution was evaporated and the residue (0·77 g.) recrystallised from acetone (30 c.c.). to give pale yellow prisms (0·55 g.), m. p. 176°, of methin[2-benzothiazole][2-(3-methyldihydrobenzothiazole] [cf. Hamer (*J.*, 1940, 803)]. The *hydrochloride*, obtained by addition of concentrated hydrochloric acid to an acetone solution, separated as a bright yellow powder, m. p. 232—234° (decomp.) (Found : Cl, 10·8. $C_{16}H_{13}N_2ClS_2$ requires Cl, 10·65%). The *hydrobromide* was obtained similarly separated as bright yellow needles, m. p. 259—260° (decomp.) (Found : Br, 21·4. $C_{16}H_{13}N_2BrS_2$ requires Br, 21·2%). The original benzene extracts were evaporated and the residual oil (4·6 g.) distilled with steam to remove unchanged 2-methylbenzothiazole. The non-volatile portion was treated with dilute hydrochloric acid and ether, to give a bright yellow solid (0·025 g.), which was filtered off and washed with ether. The ether, on evaporation, left a small quantity of a sticky residue from which 2 : 3-dihydro-3-methylbenzothiazole-2-thione (0·01 g.) was isolated. The ether insoluble solid was identified as methin[2-benzothiazole][2-(3-methyldihydrobenzothiazole] hydrochloride.

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