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Synthesis of 1*H*-[1]Benzothieno[3,2-*d*]azonine and [1]Benzothieno[3,2-*d*]azecine Derivatives

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Abstract

Derivatives of two new [1]benzothieno medium-ring heterocyclic systems have been prepared by ring degradation using cyanogen bromide-induced solvolysis of tetracyclic precursors.

Reaction of a hexahydro-[1]benzothieno[3,2-*g*]indolizine (4a) and a hexahydro-2*H*-[1]benzothieno[2,3-*a*]quinolizine (4b) with cyanogen bromide and magnesium oxide under solvolytic conditions yielded the hexahydro-1*H*-[1]benzothieno[3,2-*d*]azonines (5a) and (6a) and the octahydro-[1]benzothieno[3,2-*d*]azecines (5b) and (6b), respectively. Functional group interconversions of these medium-ring systems are described, including oxidations to the cyclic ketones (7) and (9).

The 11b-phenyl derivative (13) of (4a) reacted under similar conditions to give both solvolysis (14) and (16) and elimination (15) medium-ring products, the ratios depending on the solvent. By contrast the analogous 9a-phenylthienoindolizine derivative (17) under these conditions gave only the medium-ring elimination product (18) in aqueous medium, and only the equivalent solvolysis product in methanol. Both the thieno and [1]benzothienoazonine elimination products (18) and (15) appear to be mixtures of *E* and *Z* isomers.

The [1]benzothieno[3,2-*g*]indolizine bases (4a) and (13) are the first reported examples of this ring system.

Introduction

Investigations in this Department into the preparation of fused medium-ring (8–11 atoms) aza, oxaza, and dioxaza heterocycles have recently been extended to the synthesis of 4*H*-thieno[2,3-*d*]azonines and thieno[2,3-*d*]azecines.[1] This last paper included a literature survey which showed how few thieno and [1]benzothieno heterocycles of these types are known. In particular, of some 815 possible such [1]benzothieno skeletons only two, an azocine and an oxazocine, had been described.[1] The chemistry of [1]benzothiophens has recently been reviewed,[2] and there is considerable interest in the pharmacological properties of derivatives of this heterocycle as isosteres of biologically active indoles.[3,4]

This current paper describes the preparation of derivatives of the new 1*H*-[1]benzothieno[3,2-*d*]azonine and [1]benzothieno[3,2-*d*]azecine systems by ring degradation with cyanogen bromide-induced solvolysis.

[1] Browne, E. J., *Aust. J. Chem.*, 1984, **37**, 367.
[2] Scrowston, R. M., *Adv. Heterocycl. Chem.*, 1981, **29**, 171.
[3] Campaigne, E., Knapp, D. R., Neiss, E. S., and Bosin, T. R., *Adv. Drug. Res.*, 1970, **5**, 1.
[4] Bosin, T. R., and Campaigne, E. E., *Adv. Drug. Res.*, 1977, **11**, 191.

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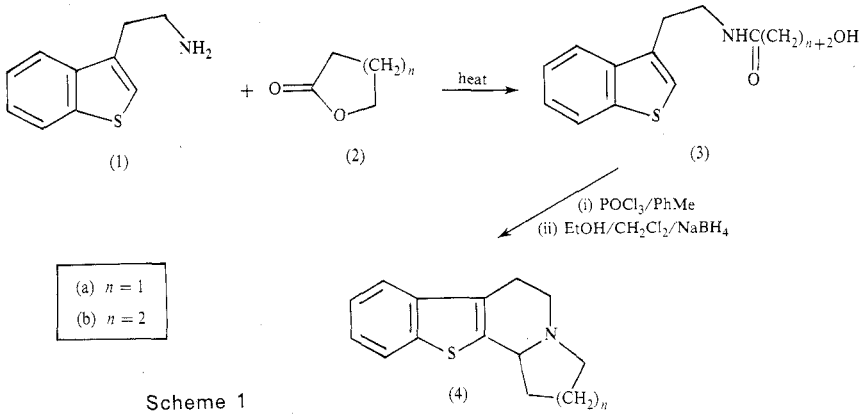
Results and Discussion

The preparations of the necessary tetracyclic precursors, the reduced [1]benzothieno[3,2-*g*]indolizine (4a), and the reduced 2*H*-[1]benzothieno[2,3-*a*]quinolizine (4b), are shown in Scheme 1.



Scheme 1

The amides (3a,b) derived from heating 2-(3-[1]benzothienyl)ethanamine (1) with the lactones (2a,b) were cyclized, without isolation, by Bischler–Napieralski-type reactions to intermediate salts; these were reduced directly with sodium tetrahydroborate to yield the bases (4a,b) in overall yields of 37% and 52% respectively. The quinolizine derivative (4b) has previously been prepared by a different route,[5] but the base (4a) is the first reported example of the [1]benzothieno[3,2-*g*]indolizine system.

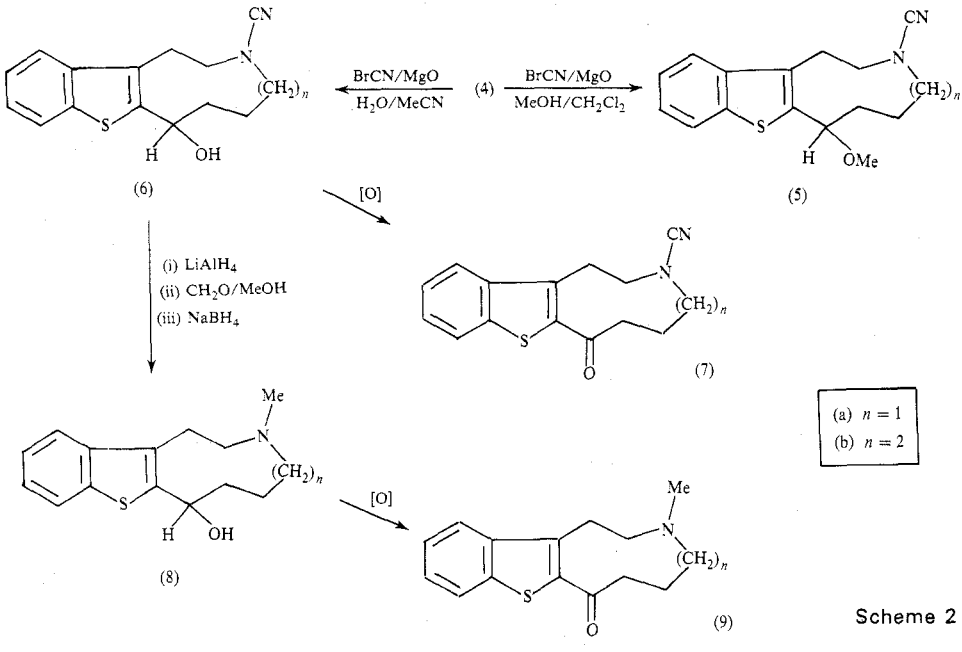
Conversion of these precursors (4a,b) into [1]benzothieno medium-ring heterocycles is shown in Scheme 2. Reaction of (4a,b) with cyanogen bromide in methanol and dichloromethane in the presence of magnesium oxide gave moderate yields of the 7-methoxy-1*H*-[1]benzothieno[3,2-*d*]azonine (5a) and the 8-methoxy-[1]benzothieno[3,2-*d*]azecine (5b) derivatives respectively. Cyanogen bromide-induced solvolysis in water and ethanenitrile gave the analogous hydroxy derivatives (6a,b) of these ring systems.

Structural assignments for (5a,b) and (6a,b) were made on analytical and spectroscopic grounds; significant features were similar to those observed for the thieno analogues.[1] However, when making such comparisons it should be noted that the medium-ring fusion in the thieno[2,3-*d*] systems is reversed relative to that in the [1]benzothieno[3,2-*d*] systems considered here. In the ^{1}H n.m.r. spectra of the latter the multiplet signals derived from the methine protons attached to the carbon bearing the methoxy or hydroxy group were centred at 5·06 (5a), 4·60 (5b), 5·52 (6a) and 5·12 (6b). These values are slightly upfield (by 17–37 Hz) from those observed in the thieno[2,3-*d*] analogues.

The hydroxy cyanamides (6a,b) were converted into the *N*-methyl alcohols (8a,b) by standard methods described previously.[1] In the ^{1}H n.m.r. spectra of (8a,b) the *N*-methyl signals appeared as singlets at δ 2·45 and 2·00 respectively. The hydroxy carbonitriles (6a,b) were oxidized to the keto carbonitriles (7a,b) with pyridinium

[5] Chapman, N. B., Hughes, C. G., and Scrowston, R. M., *J. Chem. Soc. C*, 1970, 2269.

dichromate,[6] and the tertiary amino alcohols (8a,b) oxidized to the tertiary amino ketones (9a,b) with pyridinium chlorochromate.[7] The amino alcohol (8b) and the amino ketone (9a) were crystalline solids, but the alcohol (8a) and the ketone (9b) were gums, which were converted into their methiodide salts.



Scheme 2

The infrared spectra of the new medium-ring cyclic ketones showed the following values for their carbonyl stretching frequencies (cm^{-1}):

(7a) (KCl): 1634	(7b) (KCl): 1638
(9a) (Nujol): 1624	(9b) (Nujol): 1652/1667
	(9b) methiodide (Nujol): 1626

These values are all lower than those observed for their thieno[2,3-*d*]azonine and thieno[2,3-*d*]azecine analogues.[1] The extent of this frequency reduction for the azonine derivatives (7a) and (9a) (14 cm^{-1}) and for the azecino tertiary amine (9b), is consistent with that expected for a change in the carbonyl group substitution from the 3-position to the 2-position on a thiophen[8] or a [1]benzothiophen[9,10] ring, if other features are essentially unchanged. Such lowering of frequency has been ascribed to increased conjugation of a 2-carbonyl group over that of a 3-carbonyl group,[8–10] and may be affected by other factors such as steric inhibition of resonance.[8]

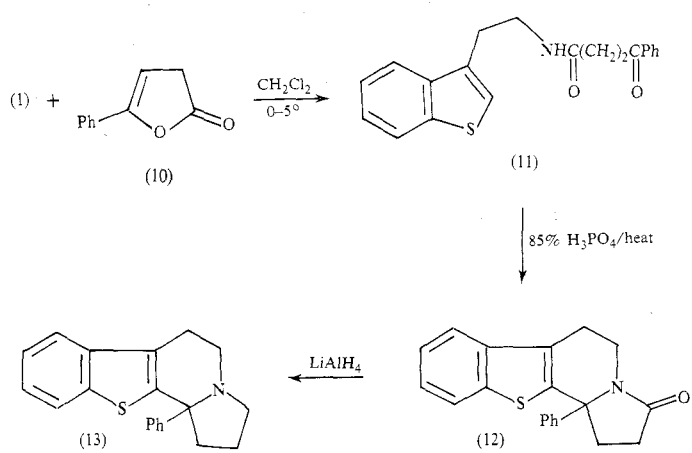
However, the observed reduction of the carbonyl stretching frequencies by 34 cm^{-1} in the spectra of the 8-oxo-[1]benzothieno[3,2-*d*]azecine-3-carbonitrile (7b) and of the methiodide salt of the 3-methyl-[1]benzothieno[3,2-*d*]azecin-8-one (9b) compared

[6] Corey, E. J., and Schmidt, G., *Tetrahedron Lett.*, 1979, 399.
[7] Corey, E. J., and Suggs, J. W., *Tetrahedron Lett.*, 1975, 2647.
[8] Gronowitz, S., *Adv. Heterocycl. Chem.*, 1963, **1**, 1.
[9] Royer, R., Demerseman, P., and Cheutin, A., *Bull. Soc. Chim. Fr.*, 1961, 1534.
[10] Iddon, B., and Scrowston, R. M., *Adv. Heterocycl. Chem.*, 1970, **11**, 177.

with those of their thieno[2,3-*d*] analogues indicates that additional factors must be operating in these cases. These could include transannular interactions arising from conformational differences, but why these should not also occur in the thieno-azecines is not clear.

Reduction in the carbonyl frequencies of fused medium-ring keto carbonitriles such as (7a) and (7b) has previously been observed for 1*H*-3-benzazonine[11] and 4*H*-thieno[2,3-*d*]azonine[1] analogues. An interaction between the carbonyl group and the cyanamide group in these cases has been suggested, and is being investigated by X-ray crystallographic analysis. The lowering of the carbonyl frequency in the *N*-methylamino ketones (9a) and (9b) is ascribed to transannular interactions between the lone electron pair on the nitrogen and the carbon of the carbonyl group (cf. ref.[1] and references cited therein).

Cyanogen bromide-induced reactions under solvolytic conditions on precursor bases such as (4a) and (4b), with a bridgehead proton and one aromatic system fused to an indolizine or quinolizine moiety, appear to give rise to medium-ring solvolysis products only, with no comparable elimination products detected. Cyanogen bromide-induced reactions under these conditions have recently been extended[1] to cases of similar precursors with a bridgehead phenyl group. For such a thieno[2,3-*g*]indolizine derivative (17) reaction in methanol did give a medium-ring solvolysis product; but with analogous benzo and 3,4-dimethoxybenzo bases under all conditions tested the only medium-ring compounds isolated were elimination products.[1]



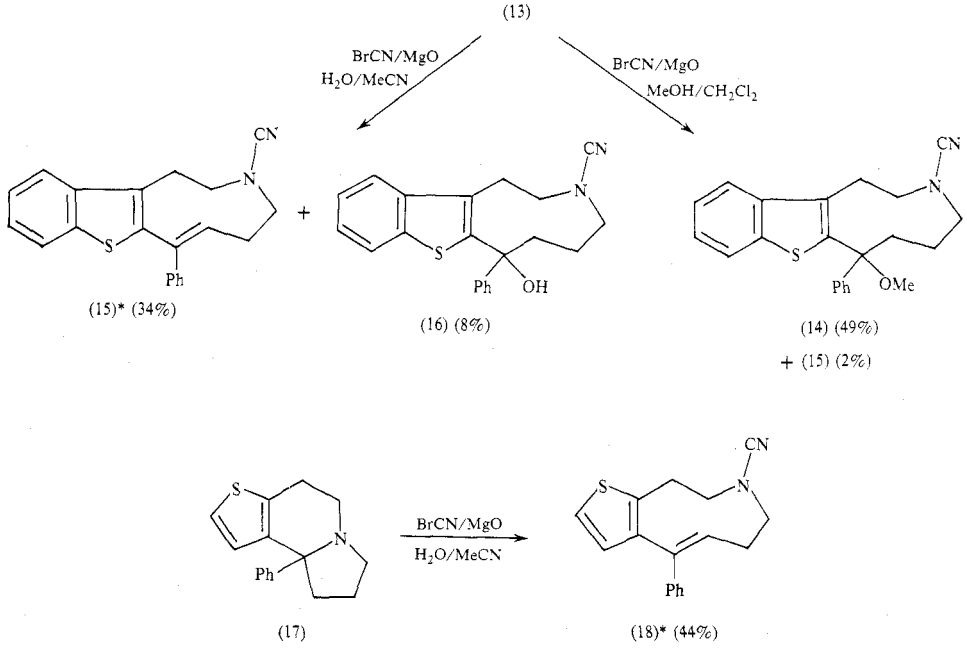
Scheme 3

The effect of the introduction of an angular phenyl group has now been further investigated on a [1]benzothieno system, by using as starting base the 11b-phenyl derivative (13) of (4a). The preparation of (13) is given in Scheme 3.

The results of the reaction of (13) with cyanogen bromide and magnesium oxide in methanol/dichloromethane or water/ethanenitrile are given in Scheme 4. In each case both medium-ring solvolysis and elimination products were isolated. However, in methanol the former was the major such product (14) (49%), and only a trace of elimination product (15) (2%) was formed. The reverse applied in the more polar aqueous medium where the main medium-ring product (15) (34%) was derived by

[11] Bremner, J. B., and Dragar, C., Abstr., 7th Nat. Conf. R.A.C.I., Div. Org. Chem., Canberra, A.C.T., WE-P9, p. 60.

elimination, while much less of the solvolysis product (16) (8%) was obtained. The mass spectra of (15) and (16) were identical apart from a weak molecular ion in that of (16).



Scheme 4. An asterisk indicates stereochemistry not specified.

The 9a-phenylthieno[2,3-*g*]indolizine derivative (17) reacted, as above, in aqueous ethanenitrile was found to give the elimination product (18) (44%) as the only medium-ring product, in contrast to its reaction in methanol which gave[1] the comparable solvolysis product (46%) only.

The course of these cyanogen bromide-induced reactions on these fused indolizines, whether solvolysis, elimination, or both, thus seems finely balanced, and dependent on both the nature and orientation of the fused aromatic ring, and the polarity of the reaction medium. It is generally accepted that the initial reaction of cyanogen bromide with a cyclic tertiary amine in the synthesis of medium-ring cyanamides is the formation of a quaternary *N*-cyanoammonium salt (cf.[1]). As the carbon atoms to which the phenyl atom is joined in bases such as (13) and (17) is doubly benzylic with respect to the nitrogen atom, and there is also considerable steric hindrance at this position, it seems probable that the subsequent step is unimolecular, giving rise to a medium-ring carbonium ion intermediate. This could then either undergo nucleophilic substitution by anions of the solvent, or eliminate an α-hydrogen atom, or both; such reactions are controlled by strong stereoelectronic effects (cf.[12]). Secondary formation of elimination products from an initially formed solvolysis product, especially in aqueous medium, remains a possibility, but appears unlikely under the mild and non-acidic conditions.

[12] Deslongchamps, P., 'Stereoelectronic Effects in Organic Chemistry' pp. 190–1 (Pergamon Press: Oxford 1983).

The stereochemistry of the medium-ring elimination products, whether (*E*) or (*Z*), has yet to be considered. In the 7-phenyltetrahydro-1*H*-3-benzazonines[1] only one isomer could be detected in each, with the ^{1}H n.m.r. signal arising from H 6 near δ 6·3 (dd or m). These compounds were considered to be more probably the *cisoid*-ring-linked (*Z*) isomers [Fig. 1(i)], as established,[13] for example, for a 6,7-dihydro-5*H*-dibenz[*c*,*g*]azonine.

(i) (*Z*) (ii) (*E*)

Fig. 1

However, for (15) and (18) spectroscopic evidence suggested that two isomers were present in each case. In the [1]benzothieno[3,2-*d*]azonine elimination product (15) the major component (A) (>90%) showed a ^{1}H n.m.r. signal derived from the alkenic proton as a triplet at δ 6·55. A minor isomer (B) (<10%) could also be detected, with the corresponding signal from the H 6 proton appearing at δ 6·13 (dd). In (B) a signal derived from CH of CH_2 was present at δ 3·97 (dd), about 0·5 ppm downfield from the lowest CH_2 signal derived from the major component (A). This suggests significant conformational differences between the two isomers.

The thieno[2,3-*d*]azonine elimination product (18) formed as a gum, indicated by ^{1}H n.m.r. spectroscopy to be a mixture of two isomers similar to those in (15), namely (A, *c.* 65%) and (B, *c.* 35%). In the spectrum of (18)(A) the signal derived from the alkenic proton appeared as a triplet at δ 6·35, and the thieno ArH signals as doublets at 6·76 and 7·20. The corresponding signals derived from the minor component (18)(B) were each upfield from the analogous ones in (18)(A), namely at δ 5·84 (dd), 6·67 (d) and 7·05 (d) respectively. As in the case of (15)(B) a signal derived from a CH of CH_2 in the spectrum of (18)(B) was observed at δ 3·89 (dd), about 0·5 ppm downfield from the lowest CH_2 signal arising from (18)(A). The spectrum of (18) was essentially unchanged on heating to 55°.

The presence of isomers (A) and (B) in (18) was confirmed by h.p.l.c. separation into two fractions with ratios in agreement with those indicated by the ^{1}H n.m.r. spectrum. The ultraviolet spectra of (A) and (B) derived from (18) were not significantly different, each having a broad, smooth band centred near 241 nm; that arising from (B) was somewhat broader than that from (A), and a slight inflexion was also present near 220 nm in the spectrum of (B) only. Definite assignments of (A) and (B) to the (*Z*) or (*E*) configurations could not be made on this evidence.

Dreiding models of the four elimination products suggested that in each case the *cisoid*-ring-linked (*Z*) configuration [Fig. 1(i)] was much less strained and less sterically hindered than the *transoid*-ring-linked (*E*) form [Fig. 1(ii)]. In particular, in the latter case the alkenic proton was turned inwards into the medium-ring, and appeared

[13] Brickwood, D. J., Hassan, A. M., Ollis, W. D., Stephanatou, J. S., and Stoddart, J. F., *J. Chem. Soc., Perkin Trans. 1*, 1978, 1393.

more shielded and more likely to undergo transannular interactions than the corresponding proton in the (*Z*) isomer. In the ^{1}H n.m.r. spectrum of both (15) and (18) the signal derived from the alkenic proton of the major component (A) was downfield from that derived from (B); therefore assignment of isomers (A) as the (*Z*) forms and of (B) as the (*E*) forms, while not unambiguously established, is thus considered to be most likely.

Experimental

Elemental analyses were carried out by the Australian Microanalytical Service, Melbourne. Melting points were determined on a Yanagimoto Seisakusho micromelting point apparatus and are uncorrected.

Mass spectra were determined on a VG MM 7070F mass spectrometer operating at 70 eV with a source temperature of 200° (direct insertion); peak intensities (in parenthesis) are expressed as a percentage of the base peak. ^{1}H n.m.r. spectra were recorded at 100 MHz with a Jeol JNM-4H-100 spectrometer, at 200 MHz with a Jeol JNM-FX-200 spectrometer, or at 300 MHz with a Bruker CXP300 spectrometer, and tetramethylsilane as internal standard; unless otherwise stated $CDCl_3$ was employed as solvent.

Infrared spectra were recorded on Beckman Acculab or IR-33 spectrometers, a JASCO 810 IR-spectrometer, or on a Digilab FTS 201E spectrometer. Ultraviolet spectra were recorded in methanol on a Varian DMS 100 ultraviolet–visible spectrophotometer.

Preparative thin-layer chromatography was performed on Camag Silica gel DSF-5, or Schleicher & Schüll silica gel 150G/LS 254; Koch–Light silica gel 100–200 mesh or Serva aluminium oxide basic, were used for column chromatography.

Mixtures of developing solvents were made up by volume. The h.p.l.c. was done with a Waters 600 solvent delivery system, coupled to a 450 variable wavelength detector, using a Waters μ-Bondapak C18 2·0 mm by 30 cm column, and aqueous methanol (30%: 70%) as solvent, at 3 ml/min and 3000 p.s.i., and ultraviolet detection at 254 nm.

Evaporations of organic solvents were done under reduced pressure in a rotary evaporator. Organic solutions were dried with anhydrous sodium sulfate. Light petroleum fractions were from within the boiling range 40–80°.

2-(3-[1]Benzothienyl)ethanamine was custom-made by Maybridge Chemical Co. Ltd., Tintagel, Cornwall, U.K.

1,2,3,5,6,11b-Hexahydro-[1]benzothieno[3,2-g]indolizine (4a)

2-([1]Benzothiophen-3-yl)ethanamine (1) (3·0 g) and 2,3,4,5-tetrahydrofuran-2-one (2a) (1·9 g) were heated together under nitrogen in an oil bath at 130–135° for 2·5 h. The syrupy amide product (3a) was cooled to 100°, toluene (60 ml) added, and freshly distilled phosphorus oxychloride (12 ml) cautiously added to the hot solution, which was then heated under reflux for 4·5 h. Solvent and excess reagent were removed in vacuum, the residue washed with light petroleum (2 × 20 ml), and dissolved in dichloromethane (20 ml) and methanol (30 ml).* The solution was cooled to 0–5° and sodium tetrahydroborate (3·0 g) was added in small portions, with ice-cooling and stirring over 4 h. The mixture was stirred at 20° for a further 17 h, the solvent removed in vacuum, and 20% aqueous sodium hydroxide (20 ml) added to the residue which was then extracted with dichloromethane (4 × 20 ml). The extracts were washed with water (2 × 10 ml), dried (sodium sulfate), and the solvent removed to leave an oil which was extracted with boiling light petroleum. Removal of this solvent left a pale yellow oil (2·04 g), which was purified by chromatography on alumina and elution with chloroform to give the *benzothienoindolizine derivative* (4a) (1·62 g, 37%) as a heat-sensitive straw-coloured syrup. ^{1}H n.m.r. δ: 1·6–2·4, m, $2CH_2$; 2·5–3·4, m, $3CH_2$; 4·0–4·2, m, H7; 7·1–7·35, m, 2ArH; 7·4–7·6, m, ArH; 7·6–7·75, m, ArH. Mass spectrum: *m/e* 229 ($M^{+\cdot}$, 67%; accurate mass 229·0942. $C_{14}H_{15}NS$ requires 229·0942), 228 (100), 201 (27), 173 (13), 155 (15), 115 (12), 99 (18). A *picrate derivative* of (4a) recrystallized from ethanol as light

* If ethanol was used as a solvent for the reduction step the product (4a) contained solvated ethanol which was difficult to remove.

orange prisms, m.p. 185–186° (Found: C, 52·7; H, 4·3; N, 12·0. $C_{14}H_{15}NS.C_6H_3N_3O_7$ requires C, 52·4; H, 4·0; N, 12·2%).

*7-Methoxy-2,3,4,5,6,7-hexahydro-1*H-[*1*]*benzothieno*[*3,2*-d]*azonine-3-carbonitrile* (*5a*)

To the tetracyclic base (4a) (0·90 g) in dry methanol (10 ml) and dichloromethane (10 ml) was added magnesium oxide (0·15 g), the mixture stirred and heated to reflux, and cyanogen bromide (0·40 g) added. Stirring and refluxing were continued for 2·0 h under nitrogen, and the solvents removed in vacuum. The residue was extracted with boiling diethyl ether (3 × 10 ml), which on cooling gave a precipitate (0·65 g). This fraction was purified by p.l.c. (silica/chloroform) to give the *methoxybenzothienoazonine* (5a) (0·41 g, 37%), R_F 0·4, recrystallized from diethyl ether as colourless prisms, m.p. 131–132° (Found: C, 66·8; H, 6·5; N, 9·6. $C_{16}H_{18}N_2OS$ requires C, 67·1; H, 6·3; N, 9·8%). ^{1}H n.m.r. δ: 0·8–1·6, m, CH_2; 1·7–3·3, $3CH_2$ and CH of CH_2; 3·34, s, OCH_3; 3·6–3·9, m, CH of CH_2; 5·06, dd, J_1 10 Hz, J_2 5 Hz, H 7; 7·15–7·4, m, 2ArH; 7·5–7·65, m, ArH; 7·7–7·85, m, ArH. Mass spectrum: *m/e* 286 ($M^{+\cdot}$, 8%; accurate mass 286·1146. $C_{16}H_{18}N_2OS$ requires 286·1140), 274 (43), 243 (25), 242 (40), 228 (16), 187 (18), 175 (17), 161 (32), 160 (17), 147 (23), 115 (18), 98 (24), 40 (100). ν_{max} (Nujol): 2190 (C≡N) cm^{-1}.

*7-Hydroxy-2,3,4,5,6,7-hexahydro-1*H-[*1*]*benzothieno*[*3,2*-d]*azonine-3-carbonitrile* (*6a*)

To a stirred solution of the base (4a) (560 mg) in ethanenitrile (10 ml) at 45° was added water (4 ml), followed by magnesium oxide (98 mg) and then cyanogen bromide (348 mg). The suspension was stirred under nitrogen at 45–50° for 2 h, the solvent removed in vacuum and water (10 ml) added to the residue. The product was extracted with dichloromethane (3 × 10 ml), the extracts were treated with charcoal, dried and concentrated to 5 ml. Addition of light petroleum gave a precipitate which was recrystallized from dichloromethane and light petroleum to give the *7-hydroxy*[*1*]*benzothienoazonine derivative* (6a) (337 mg, 52%) as colourless prisms, m.p. 197–198° (Found: C, 66·1; H, 5·8; N, 10·6. $C_{15}H_{16}N_2OS$ requires C, 66·1; H, 5·9; N, 10·3%). ^{1}H n.m.r. δ [$CDCl_3$ and $(CD_3)_2SO$]: 0·7–1·6, m, CH_2; 1·7–2·2, m, CH_2; 2·5–3·2, m, $2CH_2$ and CH of CH_2; 3·6–3·95, m, CH of CH_2; 4·9, br s, OH; 5·52, dd, J_1 11 Hz, J_2 6 Hz, H 7; 7·2–7·4, m, 2ArH; 7·45–7·6, m, ArH; 7·7–7·85, m, ArH. ν_{max} (Nujol): 2220 (C≡N), 3430 (OH) cm^{-1}.

*7-Oxo-2,3,4,5,6,7-hexahydro-1*H-[*1*]*benzothieno*[*3,2*-d]*azonine-3-carbonitrile* (*7a*)

To a suspension of pyridinium dichromate (0·49 g) and pyridinium trifluoroacetate (0·08 g)[6] in dichloromethane (10 ml) was added a warm solution of the hydroxy carbonitrile (6a) (0·32 g) in dichloromethane (20 ml) and the mixture was stirred at 20° for 18 h. The mixture was filtered and the inorganic residue washed with dichloromethane (2 × 5 ml). The combined organic solutions were washed with 5% aqueous sodium hydroxide (2 × 10 ml), and then water (10 ml). Removal of the dried solvent left a crude residue (0·22 g) which was treated by column chromatography on silica and elution with dichloromethane to give the *keto carbonitrile* (7a) (0·10 g, 31%) recrystallized from dichloromethane and light petroleum as cream prisms, m.p. 219–220° (Found: C, 66·3; H, 5·0; N, 10·3. $C_{15}H_{14}N_2OS$ requires C, 66·6; H, 5·2; N, 10·4%). ^{1}H n.m.r. δ [$CDCl_3$ and $(CD_3)_2SO$]: 2·1–2·4, m, CH_2; 2·8–3·1, m, CH_2; 3·2–3·55, m, $3CH_2$; 7·3–7·55, m, 2ArH; 7·7–8·0, m, 2ArH. Mass spectrum: *m/e* 270 ($M^{+\cdot}$, 16%; accurate mass 270·0828. $C_{15}H_{14}N_2OS$ requires 270·0827), 161 (15), 160 (100), 146 (16), 115 (20). ν_{max} (KCl): 569, 737, 768, 1076, 1126, 1190, 1248, 1315, 1342, 1474, 1514, 1634 (C=O), 2208 (C≡N), 2857, 2880, 2920, 2965 cm^{-1}.

*7-Hydroxy-3-methyl-2,3,4,5,6,7-hexahydro-1*H-[*1*]*benzothieno*[*3,2*-d]*azonine* (*8a*)

To a suspension of lithium tetrahydroaluminate (0·35 g) in dry tetrahydrofuran (20 ml) was added a warm solution of the hydroxy carbonitrile (6a) (1·10 g) in tetrahydrofuran (20 ml), and the mixture was stirred and refluxed under nitrogen for 2·5 h. Aqueous sodium hydroxide (25%, 2 ml) was added, and when decomposition was complete the mixture was filtered and the solid washed with warm dichloromethane (2 × 10 ml). The organic layers were combined, the solvents removed in vacuum, and the gummy residue (1·0 g) was at once dissolved in methanol (14 ml). Aqueous methanal (38%, 0·6 ml) was added, the solution stirred at 20° for 1·5 h, and then cooled to 0–5°. Sodium tetrahydroborate (0·9 g) was added in small portions with stirring over 1 h, and stirring continued at 20° for a further 16 h. The solvent was removed, and water (20 ml) added to the residue, which was extracted with dichloromethane (3 × 15 ml). The extracts were dried and

the solvent removed to yield a syrup (0·89 g), which was extracted with boiling light petroleum (3 × 10 ml). Removal of the solvent left the *tertiary amino alcohol* (7a) (0·64 g, 60%) as a clear gum, R_F 0·7 on chromatography on silica (dichloromethane/3% methanol). ^{1}H n.m.r. δ: 1·1–1·55, m, CH_2; 1·7–2·8, m, $3CH_2$; 2·5, br s, OH; 2·45, s, NCH_3; 2·95–3·4, m, CH_2; 5·1–5·35, m, H7; 7·15–7·4, m, 2ArH; 7·45–7·8, m, 2ArH. Mass spectrum: *m/e* 262 (M+1, 18), 261 ($M^{+\cdot}$, 88%; accurate mass 261·1182. $C_{15}H_{19}NOS$ requires $M^{+\cdot}$, 261·1186), 243 (14), 233 (16), 228 (32), 202 (28), 185 (20), 176 (22), 175 (33), 174 (21), 161 (26), 160 (22), 147 (49), 128 (17), 115 (24), 100 (44), 57 (100). ν_{max} (Nujol): 3340 (br, OH) cm^{-1}.

A *methiodide derivative* of (8a) was prepared by heating (8a) with excess iodomethane in toluene in a sealed tube at 90° for 16 h. This quaternary salt recrystallized from methanol and diethyl ether as cream prisms, m.p. 231–232° (Found: C, 47·7; H, 5·5; N, 3·4. $C_{16}H_{22}INOS$ requires C, 47·6; H, 5·5; N, 3·5%).

*3-Methyl-2,3,4,5,6,7-hexahydro-1*H-[*1*]*benzothieno*[*3,2*-d]*azonin-7-one* (*9a*)

To the tertiary amino alcohol (8a) (115 mg) in dry dichloromethane (5 ml) was added pyridinium chlorochromate[7] (264 mg) and sodium acetate (56 mg), and the mixture stirred under nitrogen at 20° for 17 h. Aqueous sodium hydroxide (8%, 4 ml) was added, and stirring continued for 1 h. The aqueous layer was washed with dichloromethane (2 × 10 ml), and the combined organic layers were washed with water (5 ml), dried, and the solvent removed in vacuum. The gummy residue was recrystallized twice from light petroleum to give the *tertiary amino ketone* (9a) (55 mg, 42%) as colourless needles, m.p. 133–134°, which contained bound cyclopentane derived from the solvent (Found: C, 71·7; H, 7·2; N, 5·1. $C_{15}H_{17}NOS.0{\cdot}5C_5H_{10}$ requires C, 71·4; H, 7·5; N, 4·8%). ^{1}H n.m.r. δ: 1·56, s, 5H (cyclopentane); 2·03, s, NCH_3; 2·0–2·5, m, $3CH_2$; 2·64, t, *J* 2 Hz, CH_2; 2·9–3·1, m, CH_2; 7·3–7·45, m, 2ArH; 7·75–7·9, m, 2ArH. Mass spectrum: *m/e* 260 (M+1, 20); 259 ($M^{+\cdot}$, 100%; accurate mass, 259·1021. $C_{15}H_{17}NOS$ requires $M^{+\cdot}$ 259·1029), 216 (82), 175 (45), 160 (73), 146 (21), 115 (24), 84 (40), 83 (22), 70 (17), 57 (67), 42 (58). ν_{max} (Nujol): 1624 (C=O) cm^{-1}.

A methiodide derivative of (9a) was prepared as above and recrystallized from methanol and diethyl ether as cream prisms, m.p. 224–225° (Found: C, 48·3; H, 5·3; N, 3·5. $C_{16}H_{20}INOS$ requires C, 47·9; H, 5·0; N, 3·5%).

*1,3,4,6,7,12b-Hexahydro-2*H-[*1*]*benzothieno*[*2,3*-a]*quinolizine* (*4b*)

2-([1]Benzothiophen-3-yl)ethanamine (1) (3·0 g) and 3,4,5,6-tetrahydro-2*H*-pyran-2-one (2b) (2·6 g) were heated together under nitrogen, in an oil bath at 130–140° for 3 h. The syrupy amide product (3b) was cooled to 80°, toluene (40 ml) added, followed by phosphorus oxychloride (8·0 ml), and the solution was refluxed for 3·5 h. Solvent and excess reagent were removed in vacuum and the residue washed with light petroleum (2 × 20 ml). This crude intermediate salt was dissolved in ethanol (40 ml) and dichloromethane (20 ml), the solution cooled to 0–5° and sodium tetrahydroborate (4·8 g) added in small portions over 4 h at 0–5°. The mixture was stirred at 20° for 14 h, the solvent removed in vacuum, and 10% aqueous sodium hydroxide (25 ml) added to the residue. Extraction with dichloromethane (4 × 30 ml), washing with water (2 × 10 ml), drying the extracts and removal of the solvent left a yellow syrup which was extracted with boiling light petroleum (4 × 30 ml). Evaporation of the solvent left the reduced benzothienoquinolizine (4b), which recrystallized from light petroleum as yellowish tinged prisms (2·0 g, 52%), m.p. 84–86° (lit.[5] 80–81°). ^{1}H n.m.r. δ: 1·4–2·2, m, $3CH_2$; 2·2–3·3, m, $3CH_2$ and CH; 7·05–7·35, m, 2ArH; 7·4–7·55, m, ArH; 7·6–7·8, m, ArH.

8-Methoxy-1,2,3,4,5,6,7,8-octahydro[*1*]*benzothieno*[*3,2*-d]*azecine-3-carbonitrile* (*5b*)

To the tetracyclic base (4b) (1·08 g) in dry methanol (10 ml) and dichloromethane (10 ml) was added magnesium oxide (0·25 g), the mixture stirred and heated to reflux, and cyanogen bromide (0·87 g) added. Stirring and refluxing were continued for 3 h under nitrogen, and the solvents removed in vacuum. Water (15 ml) was added and the mixture extracted with dichloromethane (2 × 20 ml). The extracts were dried, concentrated to 3 ml, and light petroleum (20 ml) added. The precipitate which formed was recrystallized from dichloromethane and light petroleum to give the *8-methoxy*[*1*]*benzothienoazecine derivative* (5b) (0·63 g, 48%) as cream prisms, m.p. 163–164° (Found: C, 67·9; H, 6·7; N, 9·2. $C_{17}H_{20}N_2OS$ requires C, 68 0; H, 6·7; N, 9·3%). ^{1}H n.m.r.

δ: 1·1–1·8, m, $2CH_2$; 1·8–2·2, m, CH_2; 2·6–3·2, m, $2CH_2$; 3·08, s, OCH_3; 3·2–3·5, m, CH_2; 4·45–4·75, m, H8; 7·0–7·8, m, 4ArH. Mass spectrum: *m/e* 300 ($M^{+\cdot}$, 34%; accurate mass 300·1291. $C_{17}H_{20}N_2OS$ requires 300·1296), 285 (45), 269 (10), 173 (10), 160 (12), 147 (11), 132 (74), 117 (26), 104 (100), 91 (63). ν_{max} (Nujol): 2200 (C≡N) cm^{-1}.

*8-Hydroxy-1,2,3,4,5,6,7,8-octahydro[1]benzothieno[3,2-*d*]azecine-3-carbonitrile* (*6b*)

To the base (4b) (1·97 g) in ethanenitrile (32 ml) at 40° was added water (12 ml) followed by magnesium oxide (0·49 g) and cyanogen bromide (1·30 g), and the suspension was stirred under nitrogen at 45–50° for 2 h. The solvent was removed in vacuum, water (20 ml) added and the mixture extracted with dichloromethane (4 × 20 ml). The extracts were treated with charcoal, dried, concentrated to 20 ml and light petroleum added. The precipitate was recrystallized from dichloromethane and light petroleum to give the *8-hydroxy[1]benzothienoazecine derivative* (6b) as cream prisms, m.p. 198–199° (1·04 g, 45%) (Found: C, 66·8; H, 6·4; N, 9·8. $C_{16}H_{18}N_2OS$ requires C, 67·1; H, 6·3; N, 9·8%). ^1H n.m.r. δ: 1·5–1·8, m, $2CH_2$; 1·9–2·2, m, CH_2; 2·8–3·2, m, $2CH_2$; 3·2–3·55, m, CH_2; 5·12, apparent t, *J* 7 Hz, H8; 5·1, br s, OH; 7·2–7·4, m, 2ArH; 7·4–7·6, m, ArH; 7·65–7·8, m, ArH. ν_{max} (Nujol): 2210 (C≡N), 3420 (OH) cm^{-1}.

*8-Oxo-1,2,3,4,5,6,7,8-octahydro[1]benzothieno[3,2-*d*]azecine-3-carbonitrile* (*7b*)

To the hydroxy carbonitrile (6b) (184 mg) in dry dichloromethane (20 ml) was added pyridinium dichromate (555 mg) and pyridinium trifluoroacetate (80 mg),[6] and the mixture was stirred at 20° under nitrogen for 18 h. Workup as for (7a) gave the *keto carbonitrile* (7b) (81 mg, 44%) recrystallized from diethyl ether and light petroleum as cream prisms, m.p. 111–112° (Found: C, 67·2; H, 5·5; N, 9·6. $C_{16}H_{16}N_2OS$ requires C, 67·6; H, 5·7; N, 9·9%). ^1H n.m.r. δ: 1·65–2·1, m, $2CH_2$; 2·7–3·0, m, $2CH_2$; 3·2–3·4, m, $2CH_2$; 7·2–7·5, m, 2ArH; 7·5–7·9, m, 2ArH. Mass spectrum: *m/e* 285, 284 ($M^{+\cdot}$, 32%; accurate mass 284·0985. $C_{16}H_{16}N_2OS$ requires 284·0983), 255 (8), 240 (7), 187 (14), 175 (15), 161 (21), 160 (100), 147 (21), 146 (29), 115 (21). ν_{max} (KCl): 527, 768, 1204, 1229, 1269, 1364, 1447, 1510, 1638 (C=O), 2210 (C≡N), 2859, 2882, 2940, 3011, 3057 cm^{-1}.

*8-Hydroxy-3-methyl-1,2,3,4,5,6,7,8-octahydro[1]benzothieno[3,2-*d*]azecine* (*8b*)

The hydroxycarbonitrile (6b) (1·20 g) was converted into the N-*methylamino alcohol* (8b) by the method used for the preparation of (8a). The dichloromethane-soluble product was recrystallized from diethyl ether and light petroleum as colourless prisms, m.p. 110–111° (0·71 g, 62%) (Found: C, 69·8; H, 7·7; N, 4·9. $C_{16}H_{21}NOS$ requires C, 69·8; H, 7·7; N, 5·1%). ^1H n.m.r. δ: 1·1–2·2, m, $3CH_2$; 2·00, s, NCH_3; 2·9, br s, OH; 2·4–3·1, m, $3CH_2$; 5·36, apparent t, *J* 8 Hz, H8; 7·2–7·4, m, 2ArH; 7·5–7·85, m, 2ArH. Mass spectrum: *m/e* 275 ($M^{+\cdot}$, 19%; accurate mass 275·1359. $C_{16}H_{21}NOS$ requires 275·1344), 257 (8), 243 (15), 242 (22), 200 (12), 185 (12), 175 (14), 147 (24), 115 (20), 100 (27), 98 (55), 58 (100). ν_{max} (Nujol): 3200 (br, OH) cm^{-1}.

*3-Methyl-1,2,3,4,5,6,7,8-octahydro[1]benzothieno[3,2-*d*]azecin-8-one* (*9b*)

The tertiary amino alcohol (7b) (92 mg) in dichloromethane (5 ml) was oxidized with pyridinium chlorochromate[7] (180 mg) in the presence of sodium acetate (30 mg), by the method described for the preparation of (9a), to give the N-*methylamino ketone* (9b) (65 mg, 71%) as a straw-coloured syrup (silica/chloroform) (R_F 0·2). ^1H n.m.r. δ: 1·4–1·7, m, CH_2; 1·75–2·05, m, CH_2; 1·85, s, NCH_3; 2·35–2·8, m, $3CH_2$; 2·95–3·2, m, CH_2; 7·2–7·5, m, 2ArH; 7·6–7·9, m, 2ArH. Mass spectrum: *m/e* 274 (21) (M+1), 273 ($M^{+\cdot}$, 100%; accurate mass 273·1186. $C_{16}H_{19}NOS$ requires $M^{+\cdot}$, 273·1186), 244 (15), 230 (27), 202 (25), 201 (30), 175 (26), 160 (24), 147 (24), 146 (25), 115 (23), 98 (57), 97 (39). ν_{max} (Nujol): 1667, 1652. (C=O) cm^{-1}.

A *methiodide derivative* of (9b) was prepared as above as cream prisms, m.p. 247–248° (Found: C, 49·2; H, 5·4; N, 3·4. $C_{17}H_{22}INOS$ requires C, 49·2; H, 5·3; N, 3·4%). ν_{max} (Nujol): 1626 (C=O) cm^{-1}.

N-[*2*-([*1*]*Benzothiophen-3-yl*)*ethyl*]-*4-oxo-4-phenylbutanamide* (*11*)

2-([1]Benzothiophen-3-yl)ethanamine (1) (6·1 g) in dry dichloromethane (10 ml) was added to an ice-cold solution of 5-phenyl-2,3-dihydrofuran-2-one[14] (10) (7·0 g) in dichloromethane (20 ml)

[14] Miller, G. A., Heindel, N. D., and Minatelli, J. A., *J. Heterocycl. Chem.*, 1981, **18**, 1253.

and the solution was stirred under nitrogen at 0–5° for 7 h. The precipitate (4·6 g) was filtered off and washed with dry diethyl ether. The filtrate and washings were evaporated in vacuum, and the residue triturated with cold diethyl ether. The total ether-insoluble products were recrystallized from ethanol to give the *butanamide derivative* (11) (9·9 g, 89%) as cream plates, m.p. 100–101° (Found: C, 71·2; H, 5·9; N, 4·0. $C_{20}H_{19}NO_2S$ requires C, 71·2; H, 5·7; N, 4·2%). ^{1}H n.m.r. δ: 2·50, t, *J* 6 Hz, CH_2; 2·98, t, *J* 6 Hz, CH_2; 3·26, t, *J* 6 Hz, CH_2; 3·4–3·7, m, CH_2; 6·0, br s, NH; 7·05–7·5, m, 6ArH; 7·6–7·95, m, 4ArH. ν_{max} (Nujol): 1640, 1675 (C=O), 3400 (NH) cm^{-1}.

*11b-Phenyl-1,2,3,5,6,11b-hexahydro[1]benzothieno[3,2-*g*]indolizin-3-one* (*12*)

The amide (11) (0·77 g) was added with stirring to 85% orthophosphoric acid (10 ml) preheated to 100°, and the solution was stirred and heated at 95–105° for 1 h and then poured onto ice (60 g). The product was extracted with dichloromethane (3 × 15 ml), the extracts were dried and concentrated to 5 ml. Addition of light petroleum gave a precipitate which was recrystallized from dichloromethane and light petroleum to give the *benzothienoindolizinone derivative* (12) (0·60 g, 82%) as cream flat rods, m.p. 158–159° (Found: C, 75·0; H, 5·5; N, 4·3. $C_{20}H_{17}NOS$ requires C, 75·2; H, 5·4; N, 4·4%). ^{1}H n.m.r. δ: 2·4–3·2, m, $3CH_2$ and CH of CH_2; 4·25–4·55, m, CH of CH_2; 7·1–7·55, m, 8ArH; 7·7–7·85, m, ArH. ν_{max} (Nujol): 1680 (C=O) cm^{-1}.

*11b-Phenyl-1,2,3,5,6,11b-hexahydro[1]benzothieno[3,2-*g*]indolizine* (*13*)

A solution of the cyclic amide (12) (6·0 g) in warm tetrahydrofuran (50 ml) was added with stirring to lithium tetrahydroaluminate (1·7 g) in tetrahydrofuran (60 ml), and the suspension was stirred under nitrogen at reflux temperature for 8 h. Aqueous sodium hydroxide (3·0 ml, 25% w/v) and then water (1·0 ml) were added to the mixture and, when decomposition was complete, the solvent was removed in vacuum. The residue was extracted with hot dichloromethane (3 × 20 ml), the extracts were dried, and the solvent was removed. The crude product was recrystallized from light petroleum to give the *benzothienoindolizine derivative* (13) (5·1 g, 89%) as colourless prisms, m.p. 131–132° (Found: C, 78·9; H, 6·5; N, 4·5. $C_{20}H_{19}NS$ requires C, 78·6; H, 6·3; N, 4·6%). ^{1}H n.m.r. δ: 0·7–2·2, m, $2CH_2$; 2·3–2·6, m, CH_2; 2·7–3·3, m, $2CH_2$; 7·0–7·8, m, 9ArH. Mass spectrum: *m/e* 305 ($M^{+\cdot}$ 19%; accurate mass 305·1239, $C_{20}H_{19}NS$ requires 305·1238), 304 (12), 276 (10), 229 (27), 228 (100), 137 (13), 115 (13).

*7-Methoxy-7-phenyl-2,3,4,5,6,7-hexahydro-1*H-[*1*]*benzothieno*[*3,2-*d]*azonine-3-carbonitrile* (*14*)

To the benzothienoindolizine (13) (1·33 g) in dry methanol (20 ml) and dichloromethane (20 ml) was added magnesium oxide (0·20 g) followed by cyanogen bromide (0·59 g), and the mixture was stirred and refluxed under nitrogen for 4 h. The solvents were removed in vacuum, and water (25 ml) was added to the residue which was then extracted with dichloromethane (3 × 20 ml). The extracts were dried, concentrated to 5 ml, and light petroleum (25 ml) was added. Recrystallization of the precipitate from dichloromethane and light petroleum gave the *7-methoxybenzothienoazonine* (14) (0·77 g, 49%) as cream prisms, m.p. 184–185° (Found: C, 71·9–72·2;* H, 6·1–6·4;* N, 7·6. $C_{22}H_{22}N_2OS.0{\cdot}25\ H_2O$ requires C, 72·0; H, 6·2; N, 7·6%). ^{1}H n.m.r. δ: 1·5–2·4, m, $2CH_2$; 2·96, s, OCH_3; 2·4–3·7, m, $3CH_2$; 7·0–7·4, m, 6ArH; 7·4–7·6, m, 2ArH; 7·65–7·9, m, ArH. Mass spectrum: *m/e* 362 ($M^{+\cdot}$, 27%; accurate mass 362·1445. $C_{22}H_{22}N_2OS$ requires 362·1453), 348 (25), 347 (100), 331 (26), 263 (27), 234 (19), 115 (22), 105 (48), 91 (17), 77 (45). ν_{max} 2200 (C≡N) cm^{-1}. The filtrates were evaporated to dryness, extracted with light petroleum, and the insoluble material was recrystallized from diethyl ether to give cream prisms of the *elimination product* (15) (0·03 g, 2%).

*7-Phenyl-2,3,4,5-tetrahydro-1*H-[*1*]*benzothieno*[*3,2-*d]*azonine-3-carbonitrile* (*15*) *and*
*7-Hydroxy-7-phenyl-2,3,4,5,6,7-hexahydro-1*H-[*1*]*benzothieno*[*3,2-*d]*azonine-3-carbonitrile* (*16*)

To the benzothienoindolizine (13) (1·55 g) in ethanenitrile at 70° was added water (10 ml), followed by magnesium oxide (0·18 g) and cyanogen bromide (0·57 g), and the suspension was stirred under nitrogen at 55–60° for 4 h. The solvents were removed in vacuum, water (20 ml) added and the mixture was extracted with dichloromethane (3 × 20 ml). The extracts were washed with water (10 ml), dried and the solvents removed to leave a gum (1·5 g). Chromatography on silica

* Four determinations on two samples.

and elution with dichloromethane gave the *elimination product* (15) (0·57 g, 34%): further elution with dichloromethane/5% methanol gave the *solvolysis product* (16) as a hemihydrate (0·15 g, 8%).

The *tetrahydrobenzothienoazonine* (15) recrystallized from diethyl ether and light petroleum as colourless prisms, m.p. 134–136° (Found: C, 76·5; H, 5·7; N, 8·4. $C_{21}H_{18}N_2S$ requires C, 76·3; H, 5·5; N, 8·5%). ^{1}H n.m.r. δ: 2·2–2·4, m, CH_2; 3·0–3·5, m, $3CH_2$; 6·55, t, J 4 Hz, H6; 7·25–7·5, m, 7ArH; 7·64–7·69, m, ArH; 7·82–7·87, m, ArH. The presence of traces of a second isomer (< 10%) was suggested by additional weak peaks at δ 3·97 (dd) and 6·13 (dd). Mass spectrum: *m/e* 331 (24), 330 ($M^{+\cdot}$, 100%; $C_{21}H_{18}N_2S$ requires $M^{+\cdot}$, 330), 329 (20), 288 (10), 287 (10), 275 (10), 262 (13), 261 (32), 260 (22), 248 (17), 247 (24), 235 (11), 234 (18), 115 (13). ν_{max} (KCl): 527, 588, 891, 1059, 1082, 1140, 1153, 1285, 1387, 1435, 1447, 1458, 1491, 2201 (C≡N) cm^{-1}. The *hydroxybenzothienoazonine* (16) recrystallized from dichloromethane and light petroleum as colourless prisms, m.p. 167–168° (Found: C, 71·0; H, 5·8; N, 7·7. $C_{21}H_{20}N_2OS.0{\cdot}5H_2O$ requires C, 70·6; H, 5·9; N, 7·8%). ^{1}H n.m.r. δ: 1·8–2·2, m, CH_2; 2·2–2·6, m, $3CH_2$; 2·8, br s, OH and $0{\cdot}5H_2O$; 3·3–3·7, m, CH_2; 7·1–7·6, m, 8ArH; 7·7–7·9, m, ArH. Mass spectrum: *m/e* 348 ($M^{+\cdot}$, 2%; $C_{21}H_{20}N_2OS$ requires $M^{+\cdot}$, 348), 331 (24), 330 (100), 329 (20), 288 (11), 287 (9), 275 (12), 262 (16), 261 (38), 260 (22), 248 (19), 247 (25), 235 (12), 234 (18), 228 (35), 115 (14). ν_{max} (Nujol): 2200 (C≡N), 3400 (OH and H_2O) cm^{-1}.

4-Phenyl-7,8,9,10-tetrahydro-6H-thieno[2,3-d]azonine-8-carbonitrile (18)

To the thieno[2,3-*g*]indolizine derivative[1] (17) (0·83 g) in ethanenitrile (20 ml) at 50° was added with stirring water (3 ml), followed by magnesium oxide (0·15 g) and cyanogen bromide (0·36 g). The mixture was stirred and heated under nitrogen at 50–60° for 2 h, and the solvents were removed in vacuum. The residue was extracted with diethyl ether (2 × 10 ml), dried, and the solvent removed to give a yellow gum (0·85 g). This material was passed through a silica column in dichloromethane, and the first material eluted (0·63 g) was further purified by p.l.c. (silica/dichloromethane) to give the *tetrahydrothienoazonine derivative* (18) (R_F 0·7) (0·40 g, 44%) as a straw-coloured gum. ^{1}H n.m.r. indicated the presence of two isomers (A) and (B) in a ratio of *c.* 2 : 1, namely δ: (A 2·15–2·25, m; B 2·4–3·2, m; A 2·95–3·15, m; A 3·25–3·4, m; B 3·89, dd, J_1 8 Hz, J_2 4 Hz) $4CH_2$; B 5·84, dd, J_1 5 Hz, J_2 3 Hz; A 6·35, t, J 4 Hz, H5; B 6·67, d, J 3 Hz, ArH; A 6·76, d, J 3 Hz, ArH; B 7·05, d, J 3 Hz, ArH; A 7·20, d, J 3 Hz, ArH; AB 7·15–7·37, m, 5ArH. Mass spectrum: *m/e* 280 ($M^{+\cdot}$, 49%; accurate mass 280·1029. $C_{17}H_{16}N_2S$ requires 280·1033), 279 (19), 211 (29), 210 (23), 203 (51), 197 (28), 185 (25), 184 (33), 178 (100), 176 (27), 165 (33), 152 (22), 115 (38). ν_{max} (Nujol): 2200 (C≡N) cm^{-1}. λ_{max} (log ε): 241 nm (4·38).

The mixed isomers (18) were submitted to h.p.l.c. under the conditions given in the introduction to the Experimental, and gave two fractions in the ratio of *c.* 2 : 1, with the major component (A) eluting first.

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