Synthesis and Reactions of 2,3,5,6-Tetrahydro-2,5-ethano-3-benzazocin-4(1*H*)-one and a Thieno-extended Analogue: X-Ray Structure of 3-Methyl-2,3,5,6-tetrahydro-2,5-ethano[1]benzothieno[3,2-*d*]azocin-4(1*H*)-one

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5,6,7,8,9,10-Hexahydro-6,9-methanobenzocyclo-octen-11-one (**3**) was prepared through condensation of *o*-xylene-α,α′-diyl dibromide with *N*-cyclopentylidenepyrrolidine and converted by Beckmann rearrangement of its oxime (**4**) into 2,3,5,6-tetrahydro-2,5-ethano-3-benzazocin-4(1*H*)-one (**6**). 2,3-Bis(bromomethyl)benzo[*b*]thiophene was converted similarly into a mixture of 1,4,5,6-tetrahydro-2,5-ethano[1]benzothieno[2,3-*d*]azocin-3(2*H*)-one (**15**) and the isomeric lactam (**19**). Lactam (**6**) was *N*-methylated and both the parent lactam (**6**) and the *N*-methyl derivative (**23**) were reduced with lithium aluminium hydride to the saturated products (**24**) and (**25**), respectively. Conversion of lactam (**6**) into the corresponding thiolactam (**26**) with phosphorus pentasulphide followed by alkylation of the latter compound gave an *N*- (**29**) or *S*-alkylated derivative, (**27**) or (**28**), depending on the reagent and reaction conditions. Similar reactions are reported also for lactams (**15**) and (**19**). The 4(1*H*)-one structures of compounds (**15**)–(**22**) are based on an X-ray analysis of 3-methyl-2,3,5,6-tetrahydro-2,5-ethano[1]benzothieno[3,2-*d*]azocin-4(1*H*)-one (**20**). We also report syntheses of 2-azido-5,6,7,8,9,10-hexahydro-6,9-methanobenzocyclo-octen-11-one (**33**) and 3-nitro(and 1,3-dinitro)-6,7,8,9,10,11-hexahydro-7,10-methanocyclo-octa[*b*][1]benzothiophen-12-one, (**36**) and (**37**), respectively.

For the morphinan, benzomorphan, and related opioid analgesics it is well known that their efficacy is affected by the relationship between their tertiary nitrogen atom and aromatic ring (especially in the more active phenolic compounds).[1–3] In our search for potential analgesics we have investigated changing this relationship *via*: (*a*) ring expansion of the B-ring of 3,6-dimethyl-3,4,5,6-tetrahydro-2,6-methano-3-benzazocin-1(2*H*)-one (**1**) to a 7-membered ring by Beckmann rearrangement of its oxime;[4] and (*b*) conversion of 3,6-dimethyl-1,2,3,4,5,6-hexahydro-2,6-methano-3-benzazocin-11-one (**2**) into 3,6-dimethyl-1,2,3,4-tetrahydro-3-benzazocine-2-carbonitrile through a second-order Beckmann reaction of its oxime.[5] Our interest in these Beckmann reactions coupled with the appearance, in 1982, of a paper by Bélanger *et al.*[6] describing the synthesis of 11-substituted 5,6,7,8,9,10-hexahydro-6,9-methanobenzocyclo-octenes, prompted us to investigate the Beckmann rearrangement of the oxime (**4**).[6] This was expected to yield the novel 2,5-ethano-bridged 3-benzazocine system (**6**). Following our initial work, Bélanger's group described Beckmann rearrangements of the (*E*)- and (*Z*)-isomers of the oxime (**5**), which give lactams (**7**) and (**8**), respectively.[7]

The oxime (**4**) was obtained from the corresponding ketone (**3**) which was prepared[6] by the reaction of *o*-xylene-α,α′-diyl dibromide[8] with *N*-cyclopentylidenepyrrolidine in acetonitrile in the presence of a tertiary amine followed by hydrolysis in hot water of the resulting iminium salt (**9**).[9] For the initial condensation Bélanger *et al.*[6] used (dicyclohexyl)-ethylamine as the base, which is reported[10] to give only a 49% yield of the ketone (**3**) after hydrolysis of the iminium salt (**9**), whilst Hahn and Jatczak[11] obtained an even lower yield (19%) of the ketone (**3**) using triethylamine. Consequently, we decided to investigate this condensation reaction further.

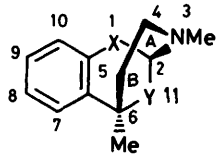
The iminium salt (**9**) precipitates from acetonitrile as it forms. Therefore, the effectiveness of added base can be measured by the rate of appearance of precipitate. We preferred to filter off the crystalline iminium salt and wash it with cold anhydrous acetonitrile prior to its hydrolysis in hot water during 2 h, which gives a product sufficiently pure for further use. It has a high m.p. of 335–337 °C and a weak IR absorption at ν_{max} 1 690 cm^{-1} (C=N; *cf.* lit.[12] values of 1 640–1 700 cm^{-1}). A slightly higher yield of ketone (**3**) is obtained by adding water to the condensation mixture followed by boiling but, in this case, the product requires recrystallising.

Table 1. Condensation of the *N*-cyclopentylidenepyrrolidine with *o*-xylene-α,α′-diyl dibromide.

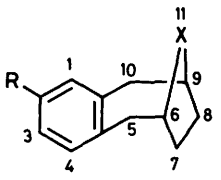
Base	Yield (%) of (**3**)
Et_3N	12–18 (lit.,[11] 19)
$Et(Pr^i)_2N$	68–76
$Et_2(C_6H_{11})N$	68–76
$Et(C_6H_{11})_2N$	49 (lit.,[10] 49)
C_5H_5N	—
$PhNMe_2$	—

The results obtained with various amines are given in Table 1. A trialkylamine substituted with sterically demanding groups appears to be preferred. These are required to deprotonate the key intermediate (**10**), thus allowing the second enamine-alkylation process to proceed. Aromatic bases, such as pyridine and *N*,*N*-dimethylaniline, probably form salts, *e.g.* diquaternary ammonium salts, with (**10**) which precipitate from the acetonitrile. Use of ethyldi-isopropylamine or, preferably, cyclohexyldiethylamine gives much improved yields of the desired ketone (**3**) compared with the literature yield of only 49%.[10]

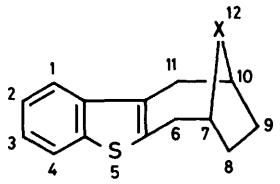
Condensation of *o*-xylene-α,α′-diyl dibromide with *N*-cyclopentylidenemorpholine in the presence of cyclohexyldiethylamine followed by hydrolysis of the resulting iminium salt gave ketone (**3**) in only ~5% yield.



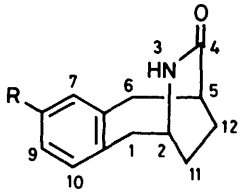
(1) X = CO, Y = CH_2
(2) X = CH_2, Y = CO



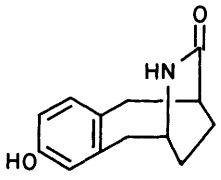
(3) R = H, X = CO
(4) R = H, X = C=NOH
(5) R = OH, X = C=NOH



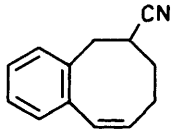
(11) X = CO
(12) X = C=NOH



(6) R = H
(7) R = OH



(8)



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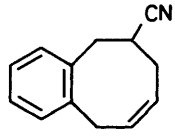

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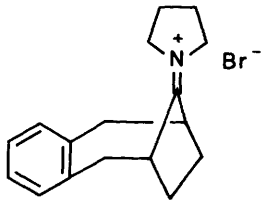
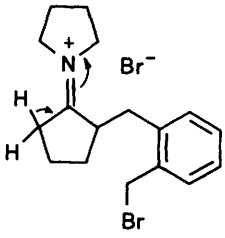
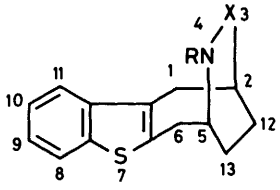


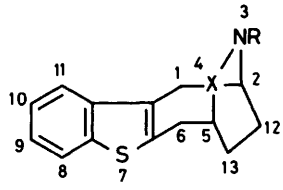
(9)



(10)



(15) R = H, X = CO
(16) R = Me, X = CO
(17) R = H, X = CS
(18) R = Me, X = CS



(19) R = H, X = CO
(20) R = Me, X = CO
(21) R = H, X = CS
(22) R = Me, X = CS

Condensation of 2,3-bis(bromomethyl)benzo[*b*]thiophene with the *N*-cyclopentylidenepyrrolidine in acetonitrile in the presence of either cyclohexyldiethylamine or ethyldiisopropylamine followed by hydrolysis of the intermediate iminium salt (which was not isolated in this case) similarly gave a 73% yield of 6,7,8,9,10,11-hexahydro-7,10-methanocycloocta[*b*][1]benzothiophen-12-one (**11**).

For the synthesis of 2,3-bis(bromomethyl)benzo[*b*]thiophene (65% yield) we bubbled the hydrogen bromide produced by bromination of *o*-xylene[8] through a stirred suspension of paraformaldehyde in acetic acid until all the paraformaldehyde had dissolved then, to the resulting clear orange solution, we added benzo[*b*]thiophene portionwise.[13] This is a highly exothermic reaction and, as the acetic acid began to reflux, the mixture was kept refluxing until addition was complete. Bromination of 2,3-dimethylbenzo[*b*]thiophene with *N*-bromosuccinimide in carbon tetrachloride[14,15] gave only a low (<20%) yield of the bis(bromomethyl) compound. Since benzo[*b*]thiophene is commercially available we prepared 2,3-dimethylbenzo[*b*]thiophene from it through conversion into the 2,3-dibromo-derivative[16] followed by stepwise replacement of the 2- and 3-bromine atoms *via* successive bromine ⟶ lithium exchange and addition of methyl iodide (*cf.* synthesis of 2,3-dimethylthiophene from 2,3-dibromothiophene[17]).

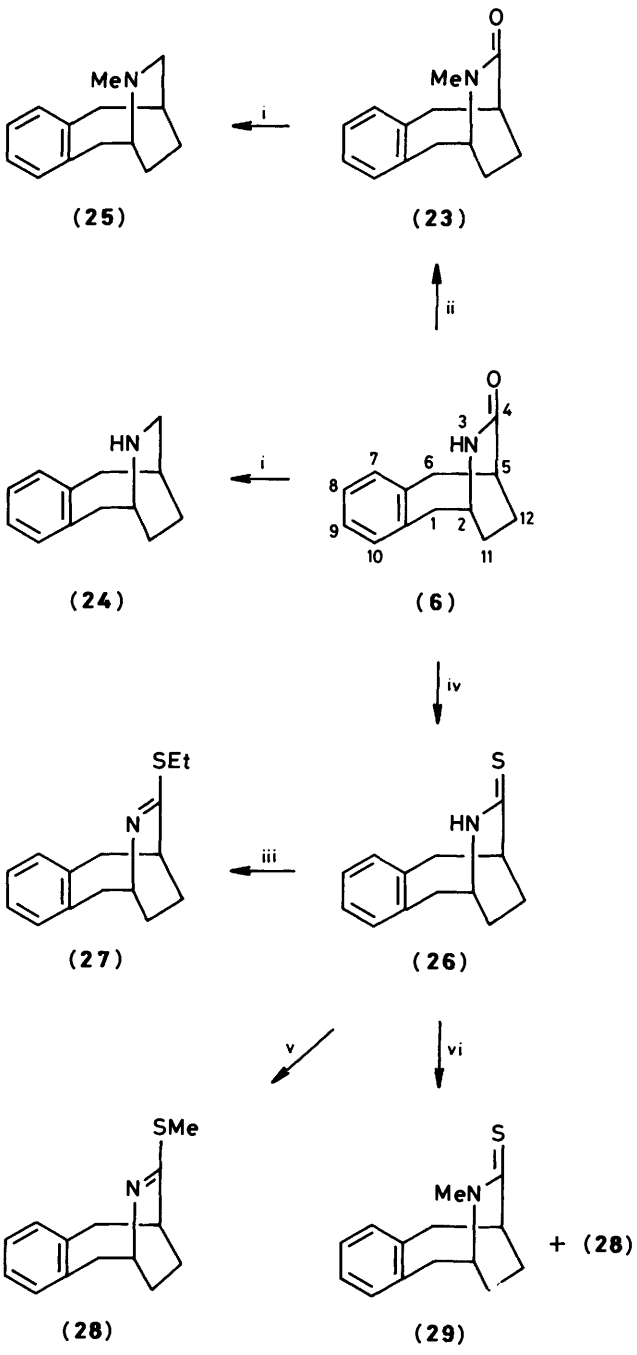
Beckmann rearrangement of the oxime (**4**) was best achieved with phosphorus pentoxide in dichloromethane at ambient temperature. This gave the expected lactam (**6**) (60% yield) together with 10–15% of a product (**13**) arising *via* a second-order Beckmann rearrangement.* This nitrile, which could not be purified either by distillation or chromatography, had ν_{max} 2 240 cm^{-1} (CN) and exhibited a benzylic methylene ^1H NMR signal integrating for only 2 protons; the alkene signals appeared at δ 6.4 (d, *J* 12.0 Hz) and 5.8 (m). These facts rule out the alternative structure (**14**).

Unsymmetrical oximes give rise to mixtures of the two possible lactam isomers, *e.g.* (**5**) ⟶ (**7**) + (**8**).[7] Similarly, when a mixture of the (*E*)- and (*Z*)-oxime (**12**) was treated with phosphorus pentoxide in dichloromethane at ambient temperature, it gave an inseparable (by column chromatography or HPLC) mixture (43% yield) of the isomeric lactams (**15**) and (**19**), respectively, in almost equal amounts, as indicated by the high field ^1H NMR spectrum (see later).† In an attempt to separate the two lactams (**15**) and (**19**), we converted them into a mixture of their corresponding 7,7-dioxides (87% yield) by oxidation with *m*-chloroperoxybenzoic acid. However, various attempts to separate these failed also.

Various derivatives of 2,3,5,6-tetrahydro-2,5-ethano-3-benzazocin-4(1*H*)-one (**6**) were prepared as shown in the Scheme. The lactam could be methylated using dimethyl sulphate but we preferred to methylate it with methyl iodide in benzene in the presence of sodium hydride. This gave the *N*-methyl-lactam (**23**) in 72% yield. Reduction of the parent lactam (**6**) and its *N*-methyl derivative (**23**) with lithium aluminium hydride in tetrahydrofuran gave compounds (**24**) (57% yield) and (**25**)

* Second-order Beckmann reactions are well established in the literature.[5,18–20]

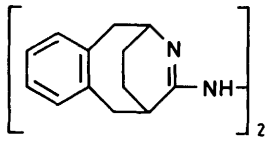
† We thank Dr. I. H. Sadler of The University of Edinburgh for this information.



Scheme. *Reagents:* i, $LiAlH_4$ in tetrahydrofuran; ii, NaH, C_6H_6, MeI; iii, $Et_3O^+BF_4^-$, CH_2Cl_2; iv, P_2S_5, pyridine; v, Me_2SO_4; vi, NaH, C_6H_6–dimethylformamide, MeI.

(55%), respectively. Treatment of the lactam (**6**) with phosphorus pentasulphide in pyridine converted it into the thione (**26**) (74% yield) which, with triethyloxonium tetrafluoroborate in anhydrous dichloromethane, gave the thioimidate (**27**) (78%) and, with dimethyl sulphate, gave the thioimidate (**28**) (64.5%). When the thione (**26**) was treated successively with sodium hydride and methyl iodide in dimethylformamide–benzene, it gave a separable mixture of the thioimidate (**28**) (15% yield) and the *N*-alkylated product (**29**) (61%).

In an attempt to generate materials with potential tranquilising properties we attempted the reaction of these thioimidates with hydrazine and acethydrazide.[21,22] Both thioimidates (**27**) and (**28**) failed to give the desired *N*-monosubstituted hydrazine; starting material was recovered. However, from the product of the reaction of the thioimidate (**27**) with hydrazine we isolated a small amount (28%) of a compound which appeared to be the *N*,*N*-disubstituted hydrazine (**30**). These thioimidates failed to react also with various primary and secondary amines.



(**30**)

Similar reactions were carried out on the mixture of lactams (**15**) and (**19**). Thus, alkylation of this mixture with methyl iodide in the presence of sodium hydride gave a mixture (80.5% yield) of the corresponding *N*-methyl derivatives, (**16**) and (**20**), respectively. This mixture was inseparable by TLC or column chromatography. In its ^1H NMR spectrum the *N*Me signals appeared at δ 2.95 and 2.90, respectively. These assignments were made tentatively following HPLC separation (see Experimental section for details) of the mixture and were based on the assumption that the signal for the *N*Me group in the *N*-methylated lactam (**16**) was likely to be slightly downfield relative to the signal for the *N*Me group in the isomer (**20**) because it is influenced not only by the adjacent carbonyl group but also by closer proximity to the ring S atom.

Treatment of the mixture of *N*-methylated lactams (**16**) and (**20**) with phosphorus pentasulphide gave a mixture (67%) of the corresponding *N*-methylated thiolactams (**18**) and (**22**), respectively, also inseparable by TLC or column chromatography. Again HPLC allowed separation both qualitatively and quantitatively; in this case isomer (**18**) was eluted first with isomer (**22**) following using n-hexane–ethyl acetate (7:3) as eluant. The ratio (45:55) of isomers corresponded favourably with the ratio of *N*-methylated lactam starting materials. We tentatively assigned the *N*Me signal in the ^1H NMR spectra at δ 3.45 to isomer (**18**) and that at δ 3.38 to isomer (**22**). Isomer (**18**) had m.p. 147–148 °C whilst isomer (**22**) had m.p. 132–133 °C. Similarly, when the mixture of the parent lactams (**15**) and (**19**) was treated with phosphorus pentasulphide in pyridine, it gave an inseparable mixture (62% yield) of the corresponding thiolactams (**17**) and (**21**), respectively.

Conclusive proof of the structures of compounds (**15**)–(**22**) came from an X-ray analysis of compound (**20**). Figure 1 shows the numbering scheme used in this analysis (see Experimental section for details) whilst Figure 2 shows the arrangement of the lactam moiety with respect to the benzo[*b*]thiophene ring together with the thermal ellipsoids.

Annelation of oxazole rings to an existing aromatic ring system is possible by heating an azide derivative in a mixture of polyphosphoric acid and, *e.g.*, acetic acid .[23–25] Therefore, we prepared 2-nitro-5,6,7,8,9,10-hexahydro-6,9-methanobenzocyclo-octen-11-one (**31**) (45% yield) by the method of Bélanger *et al.*,[6] reduced it to the corresponding amine (**32**) with tin(II) chloride in concentrated hydrochloric acid,[6] and converted this amine into the azido-ketone (**33**) (63%) by the standard procedure.[24] By heating the oxime (**34**) of this azido-ketone in a mixture of polyphosphoric acid and acetic acid we predicted that tandem oxazole ring annelation and Beckmann ring expansion might result in formation of lactam (**35**) or its isomer. In the event we were not able to isolate any identifiable compounds, although the IR spectrum of the crude product lacked the carbonyl and azide stretching frequencies of the starting material.

Nitration of the ketone (**11**) with fuming nitric acid at −35 °C

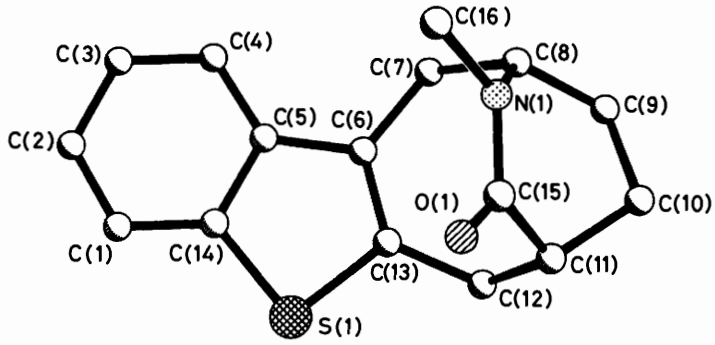


Figure 1. Numbering scheme used in X-ray analysis of compound (**20**).

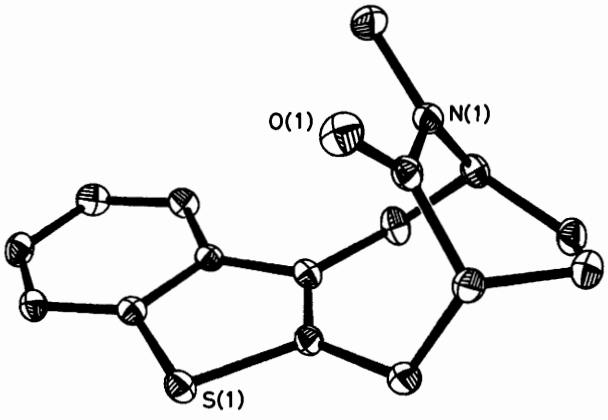
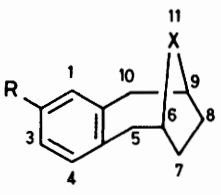
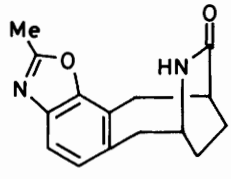


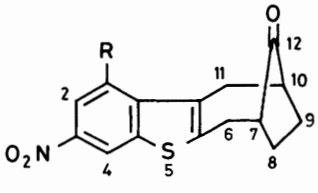
Figure 2. X-Ray structure of compound (**20**) showing arrangement of the lactam moiety with respect to the benzo[*b*]thiophene ring together with the thermal ellipsoids.





(**31**) R = NO_2, X = C=O
(**32**) R = NH_2, X = C=O
(**33**) R = N_3, X = C=O
(**34**) R = N_3, X = C=N~OH

(**35**)



(**36**) R = H
(**37**) R = NO_2

gave mainly the 1,3-dinitro derivative (**37**) (42% yield) whilst, at −65 °C, the major product was the 3-nitro derivative (**36**) (52%).

Experimental

IR spectra (liquids as films and solids as Nujol mulls between sodium chloride plates) were recorded with a Perkin-Elmer 297 spectrometer, NMR spectra with a Varian EM-360 (60 MHz), Perkin-Elmer R32 (90 MHz) (^{1}H), or Varian CFT 20 instrument (^{13}C) (with Me_4Si as an internal standard), and mass spectra with an AEI MS 12 or MS 902S instrument unless stated otherwise. M.p.s were recorded with a Gallenkamp Digital M.P. apparatus or with an Electrothermal M.P. apparatus. Small-scale distillations were carried out with a kugelrohr micro-distillation apparatus and the 'b.p.' temperatures recorded are the oven temperatures at the time of distillation.

Chromatographic separations were performed on columns packed with 'Camag' basic alumina of 100–250 mesh or Merck Kieselgel Type 60H unless stated otherwise.

Qualitative HPLC was carried out with a Waters Associates' M6000A pump coupled to a Rheodyne 7125 injector system, a 250 × 4.6 mm i.d. column packed with 5 μm Alltech silica, and a Pye Unicam 4020 UV detector system. Quantitative HPLC separations were carried out with an Altex 110 pump coupled to a Rheodyne 7125 injector system, a 250 × 10 mm i.d. column packed with 10 μm Alltech silca, and a Cecil CE 212A UV detector system.

Microanalytical (C,H,N) results were supplied by Butterworth Laboratories Ltd. of Teddington.

Light petroleum refers to the fraction of b.p. 60–80 °C, unless stated otherwise. Solvents were dried by standard procedures. In all cases organic extracts were combined, dried (with $MgSO_4$ unless stated otherwise), and evaporated on a rotary evaporator. Ether refers to diethyl ether.

The following compounds were prepared by literature methods: *o*-xylene-α,α′-diyl dibromide (52% yield), m.p. 90–93 °C (lit.,[8] 48–54% and 89–94 °C); *N*-cyclopentylidenepyrrolidine (86%), b.p. 94–96 °C at 18.0 mmHg (lit.,[9] 80–90% and 88–92 °C at 15.0 mmHg); *N*-cyclopentylidenemorpholine (73%), b.p. 120–122 °C at 18.0 mmHg (lit.,[9] 80–90% and 104–106 °C at 12.0 mmHg); 5,6,7,8,9,10-hexahydro-6,9-methanobenzocyclo-octen-11-one (**3**) (75%), m.p. 90–91 °C (lit.,[10] 49% and 90–91 °C) [procedure essentially the same as the literature procedure with the exception that cyclohexyldiethylamine was used in place of (dicyclohexyl)ethylamine; see Discussion]; 2,3-dibromobenzo-[*b*]thiophene (84%), m.p. 58–59 °C (lit.,[16] 85% and 59 °C); 2,3-bis(bromomethyl)benzo[*b*]thiophene (65%), m.p. 137–139 °C (lit.,[13] 50% and 138–139 °C); and 2-amino-5,6,7,8,9,10-hexahydro-6,9-methanobenzocyclo-octen-11-one (**32**) (86%), m.p. 97–98 °C (lit.,[6] no yield or m.p.). Oximes (**4**) and (**12**) were prepared as described previously.[4]

3-*Bromo*-2-*methylbenzo*[b]*thiophene*.—n-Butyl-lithium in hexane (1.68M; 6 ml, 10.08 mmol) was added dropwise to a stirred solution of 2,3-dibromobenzo[*b*]thiophene (2.92 g, 10.0 mmol) in anhydrous tetrahydrofuran (75 ml) at −75 °C and the mixture was kept at this temperature for 30 min. Then methyl iodide (7.3 g, 3.2 ml, 51.4 mmol) was added dropwise at −75 °C and the mixture was stirred at this temperature for a further 1 h and allowed to warm to ambient temperature. Water (100 ml) was added and the product extracted with dichloromethane (2 × 50 ml). The combined extracts were washed with water (3 × 100 ml) and dried, and evaporation gave the product (1.86 g, 82%), m.p. 40–41 °C [from light petroleum (b.p. 40–60 °C)] (lit.,[26] 42–42.5 °C); δ($CDCl_3$) 2.55 (3 H, s, Me) and 7.20–8.00 (4, m, ArH) (M^+, 226. Calc. for $C_9H_7{}^{79}BrS$: *M*, 226).

2,3-*Dimethylbenzo*[b]*thiophene*.—This compound was prepared similarly from 3-bromo-2-methylbenzo[*b*]thiophene (97%, 9.5 g, 41.85 mmol). It had b.p. 105 °C at 0.5 mmHg (lit.,[27] 122–124 °C at 13 mmHg); δ($CDCl_3$) 1.95 (3 H, s, 3-Me), 2.18 (3 H, s, 2-Me), and 6.90–7.70 (4 H, m, ArH) (M^+, 162. Calc. for $C_{10}H_{10}S$: *M*, 162).

6,7,8,9,10,11-*Hexahydro*-7,10-*methanocyclo-octa*[b][1]benzo-

thiophen-12-*one* (**11**).—Ethyldi-isopropylamine (8.0 g, 10.8 ml, 62.0 mmol) and a solution of the pyrrolidine enamine of cyclopentanone (*N*-cyclopentylidene pyrrolidine) (4.14 g, 4.4 ml, 30.0 mmol) in acetonitrile (30 ml) were added successively to a vigorously stirred solution of 2,3-bis(bromomethyl)benzo-[*b*]thiophene (9.6 g, 30.0 mmol) in acetonitrile (50 ml) heated under reflux under nitrogen and the mixture was heated under reflux for 12 h. Water (50 ml) was added and the mixture was heated for a further 1 h. Then it was cooled and 10% hydrochloric acid (10 ml) was added. The product was extracted with ether (4 × 50 ml) and the combined ethereal extracts were washed successively with saturated aqueous sodium hydrogen carbonate (100 ml) and water (2 × 100 ml), then dried. Distillation of the solvent gave the *ketone* (**11**) (5.3 g, 73%), m.p. 128–129 °C (from ethyl acetate); ν_{max} 1 730 cm^{-1} (CO); $\delta(CDCl_3)$ 1.40–2.30 (4 H, m, 8- and 9-H_2), 2.60–3.50 (6 H, m, 6- and 11-H_2 and 7- and 10-H), and 7.22–7.90 (4 H, m, ArH) (Found: C, 74.3; H, 6.3%; M^+, 242. $C_{15}H_{14}OS$ requires C, 74.4; H, 5.8%; *M*, 242).

5,6,7,8,9,10-*Hexahydro*-6,9-*methanobenzocyclo-octen*-11-*one Oxime* (**4**) *and the Oxime* (**12**).—Hydroxylamine hydrochloride (4.8 g, 69.0 mmol) was added to a solution of 5,6,7,8,9,10-hexahydro-6,9-methanobenzocyclo-octen-11-one (**3**) (8.5 g, 45.7 mmol) in 50% aqueous ethanol (200 ml) containing sodium acetate (6.0 g, 70.0 mmol) and the resulting mixture was heated under reflux for 4 h. Activated charcoal (5.0 g) was added, after cooling, and the mixture was boiled for a further 15 min. Filtration of the mixture into ice–water gave the product (**4**) (8.2 g, 89%) which was filtered off and washed with cold 50% aqueous ethanol, m.p. 136–138 °C (from ethanol) (lit.,[6] 138–139 °C).

6,7,8,9,10,11-*Hexahydro*-7,10-*methanocyclo-octa*[b][1]*benzo-thiophen*-12-*one Oxime* (**12**) (78%) was prepared similarly. It had m.p. 179–180 °C (from aqueous ethanol), ν_{max} 3 150 and 3 250 cm^{-1} (=NOH); $\delta(CDCl_3)$ 1.15–1.20 (4 H, m, 8- and 9-H_2), 2.70–3.30 (5 H, m, 6- and 11-H_2 and 7- or 10-H), 3.75 (1 H, br m, 7- or 10-H), and 7.00–7.80 (4 H, m, ArH) (Found: C, 70.05; H, 5.8; N, 5.5%; M^+, 257. $C_{15}H_{15}NOS$ requires C, 70.0; H, 5.9; N, 5.45%; *M*, 257).

2,3,5,6-*Tetrahydro*-2,5-*ethano*-3-*benzazocin*-4(1H)-*one* (**6**).—Phosphorus pentoxide (7.1 g, 50.0 mmol) was added to a stirred solution of the oxime (**4**) (2.01 g, 10.0 mmol) in dichloromethane (150 ml) and the mixture was kept at ambient temperature for 12 h, then poured into ice–water (200 ml). The aqueous phase was extracted with dichloromethane (2 × 50 ml) and the organic layer and extracts were combined, washed successively with water (200 ml), saturated aqueous sodium hydrogen carbonate (200 ml), and water (200 ml), then dried. Distillation of the solvent and fractional crystallisation of the residue from ethyl acetate gave unchanged oxime (0.6 g) and the *product* (**6**) (1.2 g, 60%), m.p. 150–151 °C (from ethyl acetate); ν_{max} 1 670 (CO) and 3 200 cm^{-1} (NH); $\delta_H(CDCl_3)$ 1.40–2.00 (4 H, m, 11- and 12-H_2), 2.98 (2 H, m, 1-H_2), 3.05 (2 H, m, 6-H_2), 3.15 (1 H, m, 2-H), 3.70–4.00 (1 H, m, 5-H), and 6.95–7.30 (4 H, m, ArH and NH); $\delta_C(CDCl_3)$ 177.40 (CO) (Found: C, 77.3; H, 7.8; N, 7.2%; M^+, 201. $C_{13}H_{15}NO$ requires C, 77.6; H, 7.5; N, 7.0%; *M*, 201).

A reaction was carried out on twice the above scale and the residue left after distillation of the solvents was chromatographed on alumina. Light petroleum (b.p. 40–60 °C)–ethyl acetate (4:1) eluted the nitrile (**13**) (0.7 g) (see Discussion) whilst light petroleum (b.p. 40–60 °C)–ethyl acetate (1:1) eluted starting material (**4**) (0.8 g) and the lactam (**6**) (2.45 g).

1,4,5,6-*Tetrahydro*-2,5-*ethano*[1]*benzothieno*[2,3-d]*azocin*-3(2H)-*one* (**15**) *and* 2,3,5,6-*Tetrahydro*-2,5-*ethano*[1]*benzo-thieno*[3,2-d]*azocin*-4(1H)-*one* (**19**).—These compounds were prepared similarly as an inseparable mixture. From 2.57 g (10.0 mmol) of the oxime (**12**) we obtained a crude product which was chromatographed on silica. Ethyl acetate–light petroleum (b.p. 40–60 °C) (1:1) eluted the oxime (0.4 g) and lactam mixture (1.1 g, 43%), m.p. 205–208 °C (decomp.) (from ethyl acetate), ν_{max} 1 658 (CO) and 3 170 cm^{-1} (NH); $\delta(CDCl_3)$ 1.72–2.18 ('4H', m, 12- and 13-H_2),* 3.19–3.72 ('4H', m, 1- and 6-H_2), 2.97, 3.07, 3.96, and 4.06 ('2H', m, 2- and 5-H), 6.90 and 7.00 ('1H', br s, NH), and 7.22–7.68 ('4H', m, ArH) (Found: 69.8; H, 5.9; N, 5.25%; M^+, 257. Calc. for $C_{15}H_{15}NOS$: C, 70.0; H, 5.9; N, 5.45%; *M*, 257).

1,4,5,6-*Tetrahydro*-2,5-*ethano*[1]*benzothieno*[2,3-d]*azocin*-3(2H)-*one* 7,7-*Dioxide and* 2,3,5,6-*Tetrahydro*-2,5-*ethano*[1]-*benzothieno*[3,2-d]*azocin*-4(1H)-*one* 7,7-*Dioxide*.—*m*-Chloroperoxybenzoic acid (1.62 g, 8.0 mmol) was added during 15 min to a stirred solution of a mixture (1.8 g, 7.0 mmol) of the foregoing compounds (**15**) and (**19**) in anhydrous dichloromethane (150 ml) at ambient temperature under nitrogen and the resulting mixture was stirred for a further 4 h. Water (100 ml) was added and the organic layer separated, washed successively with saturated aqueous sodium hydrogen carbonate (100 ml) and water (200 ml), then dried (Na_2SO_4). Distillation of the solvent gave the product (1.76 g, 87%), m.p. 262–264 °C [from dichloromethane–methanol (1:1)], ν_{max} 1 660 (CO) and 3 175 cm^{-1} (NH) (Found: C, 61.8; H, 5.25; N, 4.7%; M^+, 289. Calc. for $C_{15}H_{15}NO_3S$: C, 62.3; H, 5.2; N, 4.85%; *M*, 289).

3-*Methyl*-2,3,5,6-*tetrahydro*-2,5-*ethano*-3-*benzazocin*-4(1H)-*one* (**23**).—50% Sodium hydride in oil (0.48 g, 10.0 mmol) was added to a stirred solution of 2,3,5,6-tetrahydro-2,5-ethano-3-benzazocin-4(1*H*)-one (**6**) (0.802 g, 4.0 mmol) in anhydrous benzene (60 ml) (**CAUTION**) under nitrogen at ambient temperature and the mixture was stirred until gas evolution ceased (*ca.* 1.5 h). Methyl iodide (7.3 g, 3.2 ml, 51.4 mmol) in anhydrous benzene (20 ml) was added dropwise during 15 min, then the mixture was heated under reflux for 3 h, cooled, and filtered. Dichloromethane (100 ml) was added to the filtrate which was washed with water (2 × 100 ml) and dried. Distillation of the solvents gave a residue which was chromatographed on alumina. Elution with ethyl acetate–light petroleum (2:3) gave the *product* (**23**) (0.62 g, 72%), m.p. 135–136 °C (from ethyl acetate), ν_{max} 1 645 cm^{-1} (CO); $\delta_H(CDCl_3)$ 1.70–2.30 (4 H, m, 11- and 12-H_2), 2.65 (3 H, s, NMe), 2.98 (2 H, m, 1-H_2), 3.15 (2 H, m, 6-H_2), 3.25 (1 H, m, 2-H), 3.60–3.85 (1 H, m, 5-H), and 7.00–7.30 (4 H, s, ArH); $\delta_C(CDCl_3)$ 173.75 (CO) (Found: C, 77.8; H, 7.8; N, 6.4%; M^+, 215. $C_{14}H_{17}NO$ requires C, 78.2; H, 8.0; N, 6.5%; *M*, 215).

1,2,3,4,5,6-*Hexahydro*-2,5-*ethano*-3-*benzazocine* (**24**) *Hydrochloride*.—A stirred suspension of 2,3,5,6-tetrahydro-2,5-ethano-3-benzazocin-4(1*H*)-one (**6**) (1.0 g, 5.4 mmol) and lithium aluminium hydride (0.4 g, 10.5 mmol) in anhydrous tetrahydrofuran (200 ml) under nitrogen was heated gently under reflux and the reaction followed by TLC. After completion (24 h) and whilst cooling the mixture in an ice bath, water (0.4 ml) was added followed by 2.5M sodium hydroxide (1.2 ml), then more water (1.2 ml). The suspension was filtered off and washed with dichloromethane. Distillation of the solvents from the filtrate gave the product (**24**) (0.58 g, 57%) as a viscous oil which was converted into its *hydrochloride salt* using ethanolic hydrogen chloride, m.p. 234–236 °C [from water–methanol (1:9)] (Found: C, 69.7; H, 8.3; N, 6.3%; $M^+ - H^{35}Cl$, 187. $C_{13}H_{18}NCl$ requires C, 69.8; H, 8.1; N, 6.3%; $M - H^{35}Cl$, 187).

* Apparent integrations: the isomers were present in a *ca.* 1:1 ratio. Compounds (**19**)–(**22**) are numbered non-systematically for connection with compounds (**15**)–(**18**).

3-*Methyl*-1,2,3,4,5,6-*hexahydro*-2,5-*ethano*-3-*benzazocine* (**25**) *hydrochloride* (55%) (reaction time 8 h) was prepared similarly from compound (**23**) and had m.p. 198–199 °C (from ethanol); δ($CDCl_3$) 1.60 (4 H, m, 11- and 12-H_2), 2.98 (3 H, s, NMe), 3.27 (6 H, m, 1-, 4-, and 6-H_2), 3.90 (2 H, m, 2- and 5-H), and 7.25 (4 H, s, ArH) (Found: C, 67.2; H, 8.9; N, 5.4%; M^+ – $H^{35}Cl$·EtOH, 201. $C_{14}H_{20}NCl$·EtOH requires C, 67.7; H, 9.2; N, 4.9%; M – $H^{35}Cl$·EtOH, 201).

2,3,5,6-*Tetrahydro*-2,5-*ethano*-3-*benzazocine*-4(1H)-*thione* (**26**).—Phosphorus pentasulphide (2.22 g, 10.0 mmol) was added portionwise during 15 min to a solution of the lactam (**6**) (2.01 g, 10.0 mmol) in pyridine (60 ml) heated under reflux and the mixture was heated under reflux for a further 2.5 h, then cooled and poured into ice–water. The product was extracted with dichloromethane and the combined extracts were washed successively with 10% hydrochloric acid (3 × 50 ml) and water (2 × 150 ml), then dried. Distillation of the solvent gave the *product* (**26**) (1.6 g, 74%), m.p. 146–148 °C (from ethyl acetate), ν_{max} 3 150 cm^{-1} (NH); δ_H($CDCl_3$) 1.45–2.00 (4 H, m, 11- and 12-H_2), 2.80–3.30 (4 H, m, 1- and 6-H_2), 3.45–3.75 (1 H, m, 2-H), 3.75–4.05 (1 H, m, 5-H), 7.00–7.25 (4 H, m, ArH), and 9.48 (1 H, br s, NH); δ_C($CDCl_3$) 206.9 (CS) (Found: C, 71.65; H, 7.0; H, 6.2%; M^+, 217. $C_{13}H_{15}NS$ requires C, 71.85; H, 7.0; N, 6.45%; M, 217).

4-*Ethylthio*-1,2,5,6-*tetrahydro*-2,5-*ethano*-3-*benzazocine* (**27**).—1M Triethyloxonium tetrafluoroborate in dichloromethane (7.5 ml, 7.5 mmol) was added to a solution of 2,3,5,6-tetrahydro-2,5-ethano-3-benzazocin-4(1*H*)-thione (**26**) (1.085 g, 5.0 mmol) in anhydrous dichloromethane (40 ml) under nitrogen at ambient temperature and the mixture was stirred for 24 h. 2.5M Potassium carbonate (40 ml) was added to the cooled (ice bath) mixture and the organic and aqueous layers were separated. The aqueous layer was extracted with dichloromethane (2 × 50 ml) and the organic layer and extracts were combined, washed with water (200 ml), and dried (K_2CO_3). Distillation of the solvent gave the *product* (**27**) (0.96 g, 78%), m.p. 76–77 °C [from light petroleum (b.p. 40–60 °C)], ν_{max} 1 610 cm^{-1} (C=N); δ($CDCl_3$) 0.92 (3 H, t, *J* 8.0 Hz, Me), 1.60 (4 H, m, 11- and 12-H_2), 2.50–3.25 (7 H, m, 1- and 6-H_2, side-chain CH_2, and 2-H), 4.40 (1 H, m, 5-H), and 7.05 (4 H, s, ArH) (Found: C, 73.35; H, 7.9; N, 5.8%; M^+, 245. $C_{15}H_{19}NS$ requires C, 73.5; H, 7.8; N, 5.7%; M, 245).

4-*Methylthio*-1,2,5,6-*tetrahydro*-2,5-*ethano*-3-*benzazocine* (**28**).—The thione (**26**) (0.98 g, 4.5 mmol) was dissolved in methanol (20 ml) and 1M sodium hydroxide (10 ml) was added followed by dimethyl sulphate (0.7 g, 5.5 mmol) in methanol (5.0 ml) and the mixture was stirred at ambient temperature for 30 min, then diluted with water (50 ml) and made strongly alkaline by addition of aqueous 2.5M sodium hydroxide. The resulting precipitate was filtered off, washed well with water, and recrystallised from light petroleum (b.p. 40–60 °C) to give the *thioimidate* (**28**) (0.67 g, 64.5%), m.p. 72–73 °C, ν_{max} 1 610 cm^{-1} (C=N); δ($CDCl_3$) 1.70 (4 H, m, 11- and 12-H_2), 2.15 (3 H, s, SMe), 2.40–3.40 (5 H, m, 1- and 6-H_2 and 2-H), 4.50 (1 H, m, 5-H), and 7.10 (4 H, s, ArH) (Found: C, 72.7; H, 7.7; N, 6.0. $C_{14}H_{17}NS$ requires C, 72.8; H, 7.4; N, 6.05%).

3-*Methyl*-2,3,5,6-*tetrahydro*-2,5-*ethano*-3-*benzazocine*-4(1H)-*thione* (**29**).—50% Sodium hydride in oil (0.288 g, 6.0 mmol) was added to a stirred solution of the thione (**26**) (0.652 g, 3.0 mmol) in a mixture of anhydrous dimethylformamide (40 ml) and benzene (20 ml) (**CAUTION**) at ambient temperature and the mixture was stirred for 1 h. When evolution of gas ceased, methyl iodide (1.82 g, 0.8 ml. 12.8 mmol) in anhydrous benzene (10 ml) was added dropwise and the mixture was heated under reflux for 6 h, then cooled and filtered. Dichloromethane (100 ml) was added to the filtrate which was washed with water (2 × 100 ml), and dried (Na_2SO_4). Distillation of the solvent gave a residue which was chromatographed on alumina. Ethyl acetate–light petroleum (1:4) eluted the thioimidate (**28**) (0.1 g, 15%), m.p. 71–72 °C, ν_{max} 1 610 cm^{-1} (C:N), identical with the sample prepared as described before, and the N-*methylated thiolactam* (**29**) (0.42 g, 61%), m.p. 93 °C (from ethyl acetate), δ_H($CDCl_3$) 1.85 (4 H, m, 11- and 12-H_2), 2.56 (3 H, s, Me), 3.02 (4 H, m, 1- and 6-H_2), 3.20 (1 H, m, 2-H), 3.70 (1 H, m, 5-H), and 7.04 (4 H, s, ArH) (Found: C, 72.85; H, 7.6; N, 5.8%; M^+, 231. $C_{14}H_{17}NS$ requires C, 72.8; H, 7.4; N, 6.05%; M, 231).

Reaction of 4-*Ethylthio*-1,2,5,6-*tetrahydro*-2,5-*ethano*-3-*benzazocine* (**27**) *with Hydrazine*.—2.5M Ethanolic hydrazine (1.1 ml, 2.75 mmol) was added to a stirred solution of compound (**27**) (0.62 g, 2.52 mmol) in anhydrous ethanol (50 ml) heated under reflux under nitrogen and the mixture was heated for a further 6 h, then cooled and diluted with water (200 ml). The mixture was extracted with dichloromethane (3 × 50 ml) and the combined extracts were washed with water (5 × 100 ml), then dried. Distillation of the solvent gave a viscous residue which failed to crystallise. TLC indicated that this was a mixture. Chromatography on silica using ethyl acetate–light petroleum (3:2) as eluant gave *N*,*N*′-bis(1,2,5,6-tetrahydro-2,5-ethano-3-benzazocin-4-yl)hydrazine (**30**) (0.14 g, 28%), m.p. 302–305 °C (from ethyl acetate), ν_{max} 1 620 (C=N) and 3 200 cm^{-1} (NH); δ($CDCl_3$) 1.80 (8 H, m, 11- and 12-H_2), 2.80–3.76 (12 H, m, 1- and 6-H_2 and 2- and 5-H), 6.90 (2 H, br s, NH), and 7.10 (8 H, m, ArH) (Found: M^+, 398. Calc. for $C_{26}H_{30}N_4$: M, 398).

4-*Methyl*-1,4,5,6-*tetrahydro*-2,5-*ethano*[1]*benzothieno* [2,3-d]*azocin*-3(2H)-*one* (**16**) *and* 3-*Methyl*-2,3,5,6-*tetrahydro*-2,5-*ethano*[1]*benzothieno*[3,2-d]*azocin*-4(1H)-*one* (**20**).—60% Sodium hydride in oil (0.14 g, 3.5 mmol) was added to a stirred solution of a mixture (0.85 g, 3.3 mmol) of compounds (**15**) and (**19**) in anhydrous toluene (50 ml) at ambient temperature under nitrogen and the mixture was stirred until gas evolution ceased (2 h). Methyl iodide (1.14 g, 0.5 ml, 8.0 mmol) in anhydrous toluene (10 ml) was added dropwise during 15 min and the mixture was stirred for a further 1 h at ambient temperature, then heated under reflux for 3 h. After cooling, ice–water (50 ml) was added followed by dichloromethane (150 ml) and the organic layer was separated, washed with water (2 × 100 ml), and dried. Distillation of the solvent gave the product (0.72 g, 80.5%), m.p. 197–198 °C (from dichloromethane), ν_{max} 1 640 cm^{-1} (CO); δ($CDCl_3$) 1.70–2.30 ('4H', m, 12- and 13-H_2),* 2.90 and 2.95 ('3H', 2 × s, NMe), 2.90–3.50 ('5H', m, 1- and 6-H_2 and 2- or 5-H), 3.50–4.00 ('1H', m, 2- or 5-H), and 7.10–7.80 ('4H', m, ArH) (Found: C, 70.6; H, 6.25; N, 5.1%; M^+, 271. Calc. for $C_{16}H_{17}NOS$: C, 70.9; H, 6.3; N, 5.2%; M, 271). These compounds were separated by HPLC both qualitatively and quantitatively using n-hexane–tetrahydrofuran (1:1). Compound (**20**) was eluted first followed by compound (**16**) (ratio 54:46).

4-*Methyl*-1,4,5,6-*tetrahydro*-2,5-*ethano*[1]*benzothieno*[2,3-d]*azocine*-3(2H)-*thione* (**18**) *and* 3-*Methyl*-2,3,5,6-*tetrahydro*-2,5-*ethano*[1]*benzothieno*[3,2-d]*azocine*-4(1H)-*thione* (**22**).—Phosphorus pentasulphide (1.11 g, 5.0 mmol) was added during 15 min to a stirred solution of a mixture (1.36 g, 5.0 mmol) of the *N*-methylazocinones (**16**) and (**20**), prepared as described in the preceding experiment, in pyridine (75 ml) heated under reflux, and the mixture was heated under reflux for a further 3 h, then cooled. Water (100 ml) was added and the mixture was

* See Discussion.

Table 2. Fractional atomic co-ordinates (× 10^4) for compound (**20**).

	x/a	*y/b*	*z/c*
S(1)	982(1)	6 105(1)	2 712(1)
C(1)	1 897(5)	5 401(3)	4 559(3)
C(2)	2 712(5)	5 660(4)	5 379(3)
C(3)	3 596(5)	6 707(4)	5 474(3)
C(4)	3 630(5)	7 516(4)	4 742(3)
C(5)	2 788(4)	7 290(3)	3 892(3)
C(6)	2 646(4)	8 002(3)	3 037(3)
C(7)	3 463(6)	9 193(3)	2 951(3)
C(8)	4 444(5)	9 422(3)	2 025(3)
C(9)	3 496(6)	10 063(3)	1 227(3)
C(10)	3 099(6)	9 297(4)	374(3)
C(11)	2 821(5)	8 011(3)	692(3)
C(12)	1 337(5)	7 902(4)	1 371(3)
C(13)	1 718(4)	7 481(3)	2 357(3)
C(14)	1 932(4)	6 214(3)	3 815(3)
C(15)	4 373(4))	7 560(3)	1 135(3)
C(16)	6 651(5)	7 923(4)	2 185(3)
O(1)	4 866(4)	6 552(2)	981(2)
N(1)	5 209(4)	8332(3)	1 672(2)

Table 3. Bond lengths (Å) for compound (**20**).

S(1)–C(13)	1.746(4)	S(1)–C(14)	1.732(4)
C(1)–C(2)	1.359(6)	C(1)–C(14)	1.392(5)
C(2)–C(3)	1.397(6)	C(3)–C(4)	1.377(6)
C(4)–C(5)	1.399(5)	C(5)–C(6)	1.448(5)
C(5)–C(14)	1.412(5)	C(6)–C(7)	1.512(5)
C(6)–C(13)	1.353(5)	C(7)–C(8)	1.546(6)
C(8)–C(9)	1.541(6)	C(8)–N(1)	1.472(5)
C(9)–C(10)	1.512(6)	C(10)–C(11)	1.543(6)
C(11)–C(12)	1.546(6)	C(11)–C(15)	1.502(5)
C(12)–C(13)	1.493(6)	C(15)–O(1)	1.231(5)
C(15)–N(1)	1.341(5)	C(16)–N(1)	1.457(5)

extracted with dichloromethane (3 × 50 ml). The extracts were combined, washed successively with 10% hydrochloric acid (3 × 50 ml), saturated aqueous sodium hydrogen carbonate (100 ml), and water (2 × 100 ml), then dried. Distillation of the solvent gave the product (0.96 g, 67%), m.p. 129–130 °C [from ethyl acetate–light petroleum (3:2)]; δ($CDCl_3$) 1.70–2.20 ('4H', m, 12- and 13-H_2), 3.10–3.70 ('4H', m, 1- and 6-H_2), 3.38 and 3.45 ('3H', s, NMe), 3.70–4.20 ('2H', m, 2- and 5-H), and 7.00–7.80 ('4H', m, ArH) (Found: C, 66.65; H, 5.9; N, 4.7%; M^+, 287. Calc. for $C_{16}H_{17}NS_2$: C, 66.9; H, 6.0; N, 4.9%; *M*, 287). These compounds were separated by HPLC both qualitatively and quantitatively using n-hexane–ethyl acetate (7:3). Compound (**18**) was eluted first, m.p. 147–148 °C, followed by compound (**22**) (ratio 45:55), m.p. 132–133 °C.

1,4,5,6-*Tetrahydro*-2,5-*ethano*[1]*benzothieno*[2,3-d]*azocine*-3(2H)-*thione* (**17**) *and* 2,3,5,6-*Tetrahydro*-2,5-*ethano*[1]*benzothieno*[3,2-d]*azocine*-3(1H)-*thione* (**21**).—These compounds were prepared similarly as a mixture (0.85 g, 62%) from the mixture of lactams (**15**) and (**19**) (1.29 g, 5.0 mmol). The product had m.p. 206–208 °C (from ethyl acetate); ν_{max} 3 175 cm^{-1} (NH); δ[$CDCl_3$–$(CD_3)_2SO$] 1.80–2.20 ('4H', m, 12- and 13-H_2), 2.90–3.70 ('5H', m, 1- and 6-H_2 and 2- or 5-H), 3.90–4.30 ('1H', br m, 2- or 5-H), and 7.20–7.90 ('5H', m, ArH and NH) (Found: C, 65.7; H, 5.8; N, 5.0%; M^+, 273. Calc. for $C_{15}H_{15}NS_2$: C, 66.0; H, 5.5; N, 5.1%; *M*, 273).

2-*Azido*-5,6,7,8,9,10-*hexahydro*-6,9-*methanobenzocycloocten*-11-*one* (**33**).—Compound (**33**) was prepared by the usual procedure[24] from the corresponding amine (**32**) (10.0 mmol) and purified by chromatography on alumina. Ethyl acetate–light petroleum (b.p. 40–60 °C) (1:9) eluted the *azide* (**33**) (63%), m.p. 101–102 °C (from ethyl acetate), ν_{max} 1 738 (C:O) and 2 125 cm^{-1} (N_3); δ($CDCl_3$) 1.10–2.00 (4 H, m, 7- and 8-H_2), 2.10–2.90 (6 H, m, 5- and 10-H_2 and 6- and 9-H), and 6.70–7.20 (3 H, m, ArH) (Found: C, 68.7; H, 5.7; N, 81.5%; M^+, 227. $C_{13}H_{13}N_3O$ requires C, 68.8; H, 5.8; N, 18.5%: *M*, 227).

2-*Azido*-5,6,7,8,9,10-*hexahydro*-6,9-*methanobenzocycloocten*-11-*one* (**33**) *Oxime* (**34**).—Compound (**34**) was prepared (79%) in the usual way from (**33**) and had m.p. 129–131 °C [from ethyl acetate–light petroleum (3:1)], ν_{max} 2 120 (N_3) and 3 100–3 300 cm^{-1} (OH); δ($CDCl_3$) 1.20–1.90 (4 H, m, 7- and 8-H_2), 2.20–3.30 (5 H, m, 5- and 10-H_2 and 6- or 9-H), 3.75 (1 H, br m, 6- or 9-H), 6.52 (1 H, br s, NOH), and 6.70–7.30 (3 H, m, ArH) (Found: C, 64.65; H, 5.7; N, 22.8%; M^+, 242. $C_{13}H_{14}N_4O$ requires C, 64.5; H, 5.8; N, 23.1%; *M*, 242).

3-*Nitro*-6,7,8,9,10,11-*hexahydro*-7,10-*methanocyclo*-*octa*[b]-[1]*benzothiophen*-12-*one* (**36**) *and the Dinitro Compound* (**37**).—Powdered compound (**11**) (2.42 g, 10.0 mmol) was added during 20 min to stirred fuming nitric acid (50 ml) at −65 °C, then the mixture was poured onto crushed ice, and the precipitate filtered off, washed well with water, and recrystallised from ethyl acetate to give the product (**36**) (1.5 g, 52%), m.p. 176–178 °C; ν_{max} 1 725 cm^{-1} (C=O); δ($CDCl_3$) 1.20–2.20 (4 H, m, 8- and 9-H_2), 2.60–3.40 (6 H, m, 6- and 11-H_2 and 7- and 10-H), 7.70 (1 H, d, J_o 10.0 Hz, 1-H), 8.25 (1 H, dd, J_o 10.0, J_m 2.0 Hz, 2-H), and 8.70 (1 H, d, J_m 2.0 Hz, 4-H) (Found: M^+, 287. Calc. for $C_{15}H_{13}NO_3S$: *M*, 287).

1,3-Dinitro-6,7,8,9,10,11-hexahydro-7,10-methanocyclo-octa[*b*][1]benzothiophen-12-one (**37**) (42%) was prepared by carrying out the above procedure at −40 °C and had m.p. 250–252 °C (from dichloromethane), ν_{max} 1 720 cm^{-1} (C=O); δ($CDCl_3$) 1.20–2.20 (4 H, m, 8- and 9-H_2), 2.50–3.30 (6 H, m, 6- and 11-H_2 and 7- and 10-H), 8.40 (1 H, d, J_m 2.0 Hz, 2-H), and 8.75 (1 H, d, J_m 2.0 Hz, 4-H) (Found: M^+, 332. Calc. for $C_{15}H_{12}N_2O_5S$: *M*, 332).

X-Ray Crystallographic Analysis Data for 3-*Methyl*-2,3,5,6-*tetrahydro*-2,5-*ethano*[1]*benzothieno*[3,2-d]*azocin*-4(1H)-*one* (**20**).—*Crystal data.* Compound (**20**): $C_{16}H_{17}NOS$, M = 271.4, orthorhombic, a = 8.180(1), b = 11.348(1), c = 13.996(2) Å, U = 1 299 $Å^3$, space group $P2_12_12_1$, Z = 4, D_c = 1.39 Mg m^{-3}, μ(Mo-K_α) = 0.229 mm^{-1}, λ = 0.710 73 Å, F(000) = 576, crystal size 0.5 × 0.3 × 0.3 mm.

Data collection. All data were measured on a Nicolet R3m/V diffractometer with Mo-K_α radiation, graphite monochromated, and using the ω–2θ scan mode. Three standard reflections were measured every 100 reflections and showed no significant deterioration. The 2θ range was 3–50°, and the index range was $0 \leq h \leq 9$, $0 \leq k \leq 13$, $-2 \leq l \leq 16$. 1 606 Reflections were collected, of which 1 544 were independent and 1 344 satisfied the restriction $F > 4.0\sigma(F)$ and were used in the refinement. No correction was made for absorption. Complex neutral atom scattering factors were taken from ref. 28.

Structure determination and refinement. The structure was solved by direct methods and refined by full-matrix least-squares routines [quantity minimised $\Sigma w(F_o - F_c)^2$]. The hydrogen atoms were placed in their calculated positions, C–H = 0.96 Å, assigned fixed isotropic thermal parameters, U = 0.08 $Å^2$, and allowed to ride on their parent carbon atoms.

At convergence R = 0.041 and R_w = 0.051 where $w^{-1} = \sigma^2(F) + 0.0009F^2$. The corresponding residuals for all data were R = 0.049 and R_w = 0.052. The goodness-of-fit was 1.23, the largest Δ/σ0.001 with a data-to-parameter ratio of 7.8:1. The final difference map showed no features greater than ±0.28 e $Å^{-3}$.

Figure 1 (see Discussion) shows the numbering scheme used

Table 4. Bond angles (°) for compound (**20**).

C(13)–S(1)–C(14)	92.0(2)	C(2)–C(1)–C(14)	118.5(4)
C(1)–C(2)–C(3)	121.2(4)	C(2)–C(3)–C(4)	120.5(4)
C(3)–C(4)–C(5)	120.1(4)	C(4)–C(5)–C(6)	129.8(3)
C(4)–C(5)–C(14)	117.9(3)	C(6)–C(5)–C(14)	112.3(3)
C(5)–C(6)–C(7)	121.9(3)	C(5)–C(6)–C(13)	112.5(3)
C(7)–C(6)–C(13)	125.6(3)	C(6)–C(7)–C(8)	116.5(3)
C(7)–C(8)–C(9)	115.2(3)	C(7)–C(8)–N(1)	111.1(3)
C(9)–C(8)–N(1)	111.5(3)	C(8)–C(9)–C(10)	114.1(3)
C(9)–C(10)–C(11)	110.3(3)	C(10)–C(11)–C(12)	111.6(3)
C(10)–C(11)–C(15)	108.5(3)	C(12)–C(11)–C(15)	112.5(3)
C(11)–C(12)–C(13)	115.4(3)	S(1)–C(13)–C(6)	112.6(3)
S(1)–C(13)–C(12)	118.5(3)	C(6)–C(13)–C(12)	128.9(3)
S(1)–C(14)–C(1)	127.6(3)	S(1)–C(14)–C(5)	110.6(3)
C(1)–C(14)–C(5)	121.8(3)	C(11)–C(15)–O(1)	121.4(3)
C(11)–C(15)–N(1)	116.0(3)	O(1)–C(15)–N(1)	122.5(3)
C(8)–N(1)–C(15)	121.4(3)	C(8)–N(1)–C(16)	116.5(3)
C(15)–N(1)–C(16)	118.7(3)		

and Figure 2 the arrangement of the lactam moiety with respect to the benzo[*b*]thiophene ring together with the thermal ellipsoids. Table 2 lists the fractional atomic co-ordinates and Tables 3 and 4 the bond lengths and bond angles, respectively. All calculations were performed using the SHELXTL program suite. Thermal parameters and hydrogen atom co-ordinates have been deposited at the Cambridge Crystallographic Data Centre.*

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* For details, see Instructions for Authors, *J. Chem. Soc., Perkin Trans. 1*, 1990, Issue 1.

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