Synthesis of Thieno[2,3-*c*]- and Thieno[3,2-*c*]-azepinones[1]

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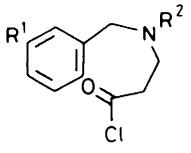
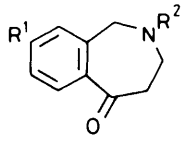
The 7-benzyl-5,6,7,8-tetrahydro-4*H*-thieno[2,3-*c*]azepin-4-one (**11**) has been synthesized from the *N*-benzyl-*N*-(2-thenyl)-β-alanine (**10**) by a tin(IV) chloride-catalysed Friedel-Crafts cyclization. In addition, *N*-benzyl- and *N*-(*p*-tolylsulphonyl)-*N*-(3-thenyl)-β-alanine (**16a**) and (**16b**) cyclized more effectively to give 5-benzyl- and 5-(*p*-tolylsulphonyl)-4,5,6,7-tetrahydro-8*H*-thieno[3,2-*c*]azepin-8-one (**17a**) and (**17b**), respectively. Attempts to remove the *p*-tolylsulphonyl group from compound (**17b**) was achieved by use of polyphosphoric acid (PPA) and afforded the 4,5,6,7-tetrahydro-8*H*-thieno[3,2-*c*]azepin-8-one (**19**). In contrast, 7-bromo-5-(*p*-tolylsulphonyl)-4,5,6,7-tetrahydro-8*H*-thieno-[3,2-*c*]azepin-8-one (**20**) gave the novel heterocyclic system, 6,7-dihydroazirino[1,2-*a*]-thieno[2,3-*d*]pyridin-8-one (**22**) under similar conditions.

The intramolecular Friedel-Crafts cyclization of the *N*-aralkyl-β-alanines (**1a**—**c**) has been well studied with regard to the synthesis of the 2-benzazepine skeleton (**2a**—**c**).[2-6] In contrast, thieno[2,3-*c*]- and thieno[3,2-*c*]-azepine systems are a poorly explored class of compounds. The 5,6,7,8-tetrahydro-4*H*-thieno[3,2-*c*]azepin-4-one (**3**) has been prepared by Beckmann[7a-c] or Schmidt[7b,8] reactions. Recently, Iddon *et al.* reported the synthesis of the 5,6,7,8-tetrahydro-4*H*-thieno[3,2-*c*]azepine-4-thione (**4**)[9] by means of an intramolecular cyclization of 3-(2-thienyl)propyl isothiocyanate and the synthesis of 6-diethylamino-8*H*-thieno[2,3-*c*]azepine (**5**)[10] as the first example of this system by means of the photolysis of 6-azidobenzo[*b*]thiophene.

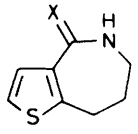


(**1**)

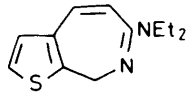


(**2**)

a: R^1 = OMe, R^2 = Ts
b: R^1 = OMe, R^2 = CH_2Ph
c: R^1 = H, R^2 = Ts



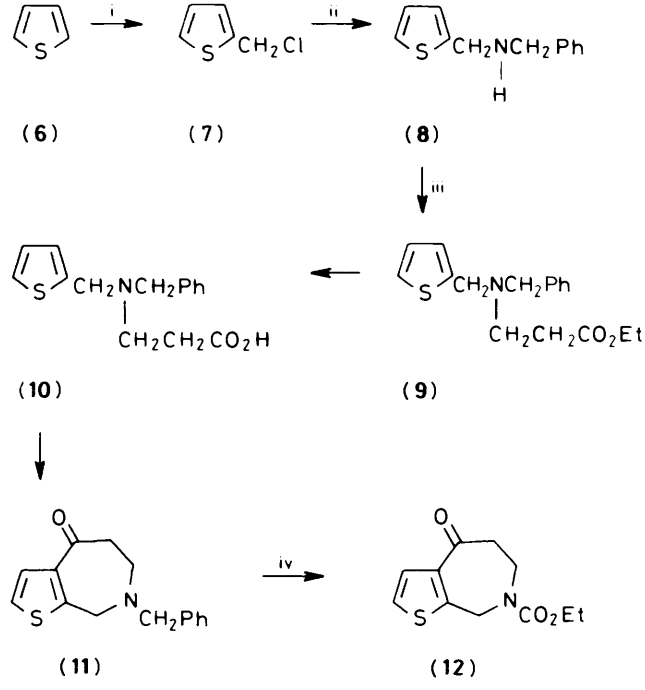
(**3**) X = O
(**4**) X = S



(**5**)

We report here practical synthetic routes to, and reactions of, thienoazepinones, *via* an intramolecular Friedel-Crafts acylation; those compounds have interesting antimicrobial activity.[11]

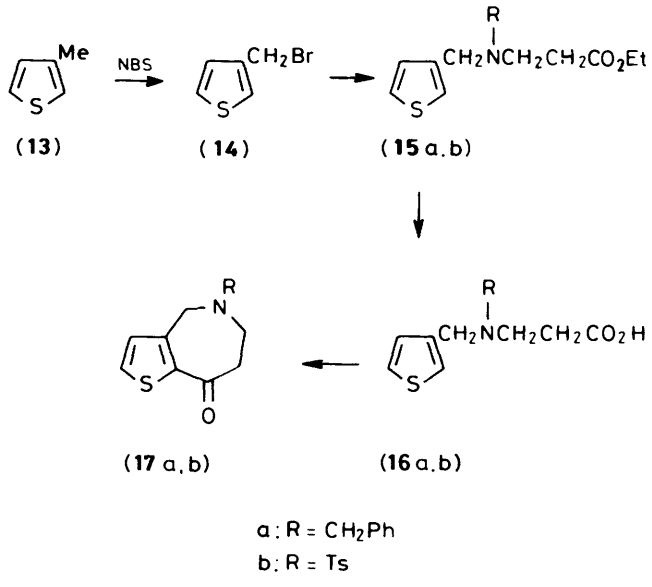
The synthesis of 7-benzyl-5,6,7,8-tetrahydro-4*H*-thieno[2,3-*c*] azepin-4-one (**11**) was achieved as shown in Scheme 1. The hydrochloride of the acid (**10**) was converted into the acyl chloride and cyclized with tin(IV) chloride to give the thienoazepinone (**11**) in relatively low yield. The structure of the ketone (**11**) was confirmed both by its ^1H n.m.r. spectrum which showed two doublets at δ 7.45 (*J* 5.4 Hz) and 7.08 (*J* 5.4 Hz)



(**6**) (**7**) (**8**) (**9**) (**10**) (**11**) (**12**)

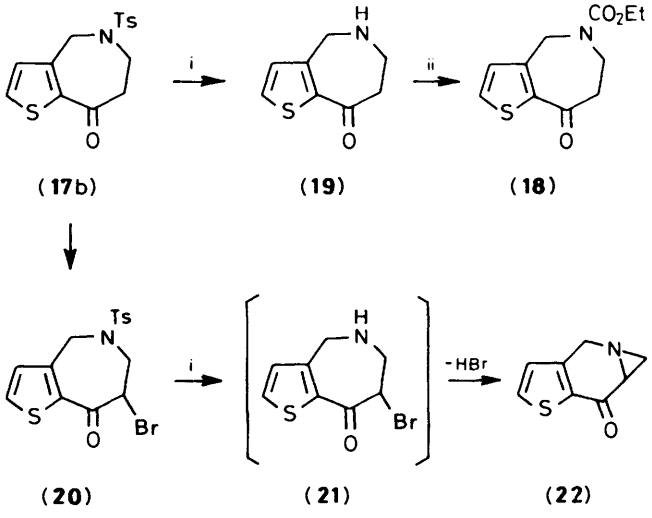
Scheme 1. *Reagents:* i, HCHO–HCl; ii, $PhCH_2NH_2$; iii, CH_2=$CHCO_2Et$; iv, $ClCO_2Et$

assigned to the α- and β-protons of the thiophene ring, respectively, and also the i.r. spectrum which showed a peak at 1 650 cm^{-1} as a stretching band of the carbonyl group attached to the β-position of the thiophene ring.[4,12a] Similarly, the *N*-substituted *N*-(3-thenyl)-β-alanine derivatives (**16a,b**) (see Scheme 2) gave acid chlorides which readily cyclized to give good yields of the thieno[3,2-*c*]azepinones (**17a,b**). The ^1H n.m.r. spectrum of 5-benzyl-4,5,6,7-tetrahydro-8*H*-thieno[3,2-*c*]azepin-8-one (**17a**) showed two doublets at δ 7.45 (*J* 5.4 Hz) and 6.76 (*J* 5.4 Hz) assigned to the α- and β-protons of thiophene ring. The i.r. spectrum exhibited a characteristic stretching band at 1 630 cm^{-1} due to the conjugated carbonyl group located at the α-position of the thiophene ring.[12b] The ^1H n.m.r. spectrum of compound (**17b**) consisted of two pseudo-triplets (*J* 5.3 Hz) at δ 3.58 and 2.92 for two methylene groups (6- and 7-H_2, respectively), two singlets at δ 2.40 and 4.66 for the methyl group



Scheme 2.

and 4-H_2, an AB quartet at δ 6.87 and 7.50 (*J* 5.3 Hz) for the thiophene ring, and two broad doublets at δ 7.22 and 7.60 (*J* 8.3 Hz) for the benzene ring. A conversion of the benzyl groups of compounds (**11**) and (**17a**) into ethoxycarbonyl groups was brought about by heating with an excess of ethyl chloroformate,[13] to give compounds (**12**) and (**18**) as colourless oils in 66 and 76% yield, respectively. The cyclized ketone (**17b**) reacted with pyridinium hydrobromide perbromide ($Py^+HBr_3^-$)[14] to give exclusively the 7-bromo compound (**20**) in 78% yield (Scheme 3). The position of the bromine atom in

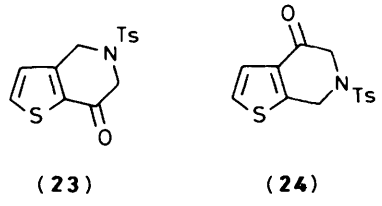


Scheme 3. *Reagents:* i, PPA; ii, $ClCO_2Et$

compound (**20**) was apparently substantiated both by the shift of the carbonyl band in the i.r. spectrum [by 15 cm^{-1} higher compared to that of compound (**17b**)][15] and by the transformation of the ^1H n.m.r. signal of 6- and 7-H from an A_2X_2 pattern for compound (**17b**) to an AMX pattern for (**20**).

Although a *p*-tolylsulphonyl group is often used for amine protection, deprotection is not necessarily smooth.[16] Heating with hydrogen bromide in acetic acid,[17] for instance, failed to remove the p-tolylsulphonyl group from compound (**17b**), but when PPA was used at 80 °C for 30 h, the detosylated compound, 4,5,6,7-tetrahydro-8*H*-thieno[3,2-*c*]azepin-8-one (**19**), was obtained (56% yield). The structure of compound (**19**) was confirmed by the analysis of the spectral data and conversion into the known *N*-ethoxycarbonyl compound (**18**) (Scheme 3). Unexpectedly, an attempt to remove a *p*-tolylsulphonyl group from the 7-bromo compound (**20**) by use of PPA gave the novel tricyclic ketone, 6,7-dihydroazirino-[1,2-*a*]thieno[2,3-*d*]pyridin-8-one (**22**) (63% yield). The ^1H n.m.r. spectrum of compound (**22**) revealed the presence of three aziridine ring-protons resonated at δ 1.83 (1 H, d, *J* 3.0 Hz), 2.42 (1 H, d, *J* 6.2 Hz), and 2.85 (1 H, dd, *J* 3.0 and 6.2 Hz), respectively. The formation of the aziridine ring during the detosylation of compound (**20**) may occur *via* the dehydrobromination of the initially formed detosylated compound (**21**) as shown in Scheme 3.

Although it was known that the Friedel-Crafts reaction of *N*-aralkyl-β-alanines was not always successful,[18] our synthesis of thienoazepines by this type of cyclization is novel. In addition, we have already found that the intramolecular cyclization can be used for the synthesis of the 2-benzazepinone derivative (**2c**) from the *N*-benzyl-β-alanine derivative (**1c**),[6] and the thieno-[2,3-*c*]- and thieno[3,2-*c*]-pyridinone derivatives (**23**) and (**24**)



from *N*-(3-thenyl)- and *N*-(2-thenyl)-glycines,[19] respectively. The yields and conditions of these intramolecular Friedel-Crafts reactions are listed in the Table.

Table. The intramolecular Friedel-Crafts cyclization of *N*-aralkyl amino acids in dry benzene

Cyclic ketone	Catalyst	Temp. (°C)	Reaction time (h)	Yield (%)
(**11**)	$SnCl_4$	80	10	15
(**17a**)*	$SnCl_4$	80	12	73
(**17b**)*	$SnCl_4$	20	17	88
(**2c**)†	$AlCl_3$	80	4	71
(**23**)‡	$SnCl_4$	20	3	64
(**24**)‡	$SnCl_4$	20	4	23

* Present work. † Ref. 6. ‡ Ref. 19.

Experimental

2-Thenyl chloride (**7**),[20] benzyl(2-thenyl)amine (**8**),[21] 3-thenyl bromide (**14**),[22] ethyl *N*-benzyl-β-alanate,[23] and ethyl *N*-(*p*-tolylsulphonyl)-β-alanate[24] were prepared according to literature procedures. M.p.s and b.p.s are uncorrected. ^1H N.m.r. spectra were recorded on a Hitachi R-20B or a JEOL PMX-60 spectrometer ($SiMe_4$ as an internal standard), i.r. spectra (films for liquids and Nujol mulls for solids) on a Jasco IRA-1 spectrometer, and electronic spectra on a Hitachi model 200-10 spectrometer. Elemental analyses were performed on a Yanagimoto CHN-2 analyser. Preparative medium-pressure (3—7 kg cm^{-2}) liquid chromatography (m.p.l.c.) was carried out on an assembled apparatus consisting of an FMI-

Lab pump, an ALTEX-MS UV-detector (254 nm), a TOA EPR-10B chart recorder, and a column (22 mm × 500 mm) packed with silica gel (Woelm 32—63).

Ethyl N-*Benzyl*-N-(2-*thenyl*)-β-*alanate* (**9**).—A mixture of benzyl(2-thenyl)amine (18.6 g, 0.09 mol) and ethyl acrylate (14.3 g, 0.14 mol) was refluxed for 3 h after which the latter was distilled off. The residue was treated with dilute hydrochloric acid and washed with ether. The acidic layer was made alkaline with aqueous potassium hydroxide and extracted with ether. The solution was dried ($MgSO_4$) and the solvent was removed under reduced pressure to give a yellow residue. Vacuum distillation of the residue gave the alanate (**9**) (21.6 g, 79%) as a colourless liquid, b.p. 128 °C/13 mmHg (Found: C, 67.1; H, 7.1; N, 4.5. $C_{17}H_{21}NO_2S$ requires C, 67.3; H, 7.0; N, 4.6%).

N-*Benzyl*-N-(2-*thenyl*)-β-*alanine* (**10**).—A mixture of the preceding ester (**9**) (3.0 g, 0.01 mol) and alcoholic potassium hydroxide (100 ml, containing 0.6 g of KOH) was refluxed for 4 h and, after cooling, the solvent was removed. After the addition of ether and water to the residue, the lower layer was neutralized with dilute hydrochloric acid, and extracted with chloroform to give the acid (**10**) (2.5 g, 91%) as a pale yellow liquid. The analytical sample was purified by column chromatography on silica gel [hexane–ethyl acetate 1:1 (v/v)] (Found: C, 65.2; H, 6.4; N, 4.9. $C_{15}H_{17}NO_2S$ requires C, 65.4; H, 6.2; N, 5.1%).

7-*Benzyl*-5,6,7,8-*tetrahydro*-4H-*thieno*[2,3-c]*azepin*-4-*one* (**11**).—The foregoing carboxylic acid (**10**) (200 mg, 0.73 mmol) was dissolved in concentrated hydrochloric acid (2 ml) to cause crystallization of the hydrochloride of (**10**) (220 mg, 97%). This was recrystallized from ethanol, m.p. 185—187 °C, $\nu_{max.}$(Nujol) 1 710 cm^{-1}.

Phosphorus pentachloride (137 mg, 0.66 mmol) was added to a suspension of the finely powdered and well dried hydrochloride (200 mg, 0.64 mmol) in benzene (25 ml) and the mixture was stirred for 6 h at room temperature until it became clear; the solvent and phosphoryl chloride which was formed during the reaction were then removed under reduced pressure. To a stirred solution of the thus obtained acid chloride in dry benzene (25 ml) was added slowly tin(IV) chloride (260 mg, 0.99 mmol) through a syringe with cooling in an ice-bath. The mixture was refluxed for 10 h and poured onto ice and hydrochloric acid (2M). The acidic aqueous layer was separated, made alkaline with potassium carbonate, and extracted with ether; the extract was then dried ($MgSO_4$) and evaporated under reduced pressure to leave a light brown liquid, which was purified by m.p.l.c. to give an unidentified liquid (15 mg) and compound (**11**) (23 mg, 15%) as a colourless liquid (Found: C, 69.8; H, 6.0; N, 5.2. $C_{15}H_{15}NOS$ requires C, 70.0; H, 5.9; N, 5.4%); $\nu_{max.}$(film) 1 650 cm^{-1} (C=O); δ($CDCl_3$) 2.95 (4 H, m), 3.72 (2 H, s), 4.12 (2 H, s), 7.08 (1 H, d, *J* 5.4 Hz), 7.35 (5 H, s), and 7.45 (1 H, d, *J* 5.4 Hz); $\lambda_{max.}$(EtOH) 253 nm (ε 11 700 dm^3 mol^{-1} cm^{-1}).

7-*Ethoxycarbonyl*-5,6,7,8-*tetrahydro*-4H-*thieno*[2,3-c]*azepin*-4-*one* (**12**).—Compound (**11**) (31 mg, 0.12 mmol) and ethyl chloroformate (55 mg, 0.51 mmol) were heated together under reflux for 28 h. After evaporation, the product was purified by m.p.l.c. [hexane–ethyl acetate (4:1, v/v)] to give compound (**12**) (19 mg, 66%) as a colourless liquid (Found: C, 55.4; H, 5.6; N, 5.7. $C_{11}H_{13}NO_3S$ requires C, 55.2; H, 5.5; N, 5.9%).

Ethyl N-*Benzyl*-N-(3-*thenyl*)-β-*alanate* (**15a**).—To a solution of ethyl *N*-benzyl-β-alanate (16.6 g, 80 mmol) and triethylamine (8.1 g, 80 mmol) in ethanol (200 ml), was added gradually a solution of 3-thenyl bromide (14.2 g, 80 mmol) in ethanol (50 ml) at room temperature; the mixture was then refluxed for 12 h. The residue obtained after removal of the ethanol was extracted with ether and the ether extract was washed with water, dried ($MgSO_4$), and evaporated. The product so obtained was distilled under reduced pressure to give (**15a**) (12.4 g, 51%) as a colourless liquid, b.p. 165—167 °C/18 mmHg (Found: C, 67.0; H, 7.0; N, 4.5. $C_{17}H_{21}NO_2S$ requires C, 67.3; H, 7.0; N, 4.6%).

Ethyl N-(3-*thenyl*)-N-(p-*tolylsulphonyl*)-β-*alanate* (**15b**).—A mixture of ethyl *N*-(*p*-tolylsulphonyl)-β-alanate (40.0 g, 147 mmol), 3-thenyl bromide (26.1 g, 147 mmol), and freshly roasted potassium carbonate (61.0 g, 440 mmol) in dry acetone (300 ml) was stirred and heated under reflux for 32 h. After cooling, the reaction mixture was poured into water (500 ml), extracted with dichloromethane, and the extract dried ($MgSO_4$) and evaporated under reduced pressure to leave a solid which was crystallized from ethyl acetate–petroleum ether to give the ester (**15b**) (43.3 g, 80%), m.p. 77—78.5 °C (Found: C, 55.7; H, 5.7; N, 3.9. $C_{17}H_{21}NO_4S_2$ requires C, 55.6; H, 5.8; N, 3.8%.

N-*Benzyl*-N-(3-*thenyl*)-β-*alanine* (**16a**)—A solution of the ester (**15a**) (420 mg, 1.4 mmol) in ethanol (25 ml) containing potassium hydroxide (90 mg) was refluxed for 7 h. A work-up similar to that described for the acid (**10**) gave the free acid (**16a**) (290 mg, 75%) as a colourless liquid (Found: C, 65.1; H, 6.4; N, 4.9. $C_{15}H_{17}NO_2S$ requires C, 65.4; H, 6.2; N, 5.1%).

N-(3-*Thenyl*)-N-(p-*tolylsulphonyl*)-β-*alanine* (**16b**).—The foregoing ester (**15b**) (10.0 g, 27.2 mmol) was heated under reflux with sodium hydroxide (1.1 g, 27.2 mmol) in water (250 ml) for 5 h after which the reaction mixture was washed with ether, poured with stirring into hydrochloric acid (2M) and extracted with ether. The extract was washed with water, dried ($MgSO_4$), and evaporated under reduced pressure to give the free acid (**16b**) (8.3 g, 90%) as a solid, which was recrystallized from aqueous ethanol, m.p. 117—118 °C (Found: C, 53.0; H, 5.0; N, 4.0. $C_{15}H_{17}NO_4S_2$ requires C, 53.1; H, 5.05; N, 4.1%).

5-*Benzyl*-4,5,6,7-*tetrahydro*-8H-*thieno*[3,2-c]*azepin*-8-*one* (**17a**).—*N*-Benzyl-*N*-(3-thenyl)-β-alanine (**16a**) (4.6 g, 16.8 mmol) on treatment with concentrated hydrochloric acid gave the (**16a**)·HCl which was filtered off (4.6 g, 93%) and recrystallized from ethanol, m.p. 198—199 °C (decomp.), $\nu_{max.}$(Nujol) 1 715 cm^{-1} (C=O).

The preceding hydrochloride (500 mg, 1.6 mmol), phosphorus pentachloride (340 mg, 1.6 mmol), and dry benzene (25 ml) were stirred for 6 h until the mixture became clear after which phosphoryl chloride, formed in the process, was removed by repeated co-distillation with dry benzene at 30 °C under reduced pressure. To a stirred and cooled solution of the acid chloride in dry benzene (30 ml) in an ice-bath was added gradually tin(IV) chloride (650 mg, 2.4 mmol) through a syringe. The mixture was then refluxed for 12 h, after which time crushed ice and concentrated hydrochloric acid (2 ml) were added carefully to the mixture. The acidic aqueous layer was separated and worked up as described for compound (**10**) to give the cyclized ketone (**17a**) (300 mg, 73%), which was purified by column chromatography [benzene–ethyl acetate (4:1, v/v)] (Found: C, 69.8; H, 6.0; N, 5.3. $C_{15}H_{15}NOS$ requires C, 70.0; H, 5.9; N, 5.4%); $\nu_{max.}$(film) 1 630 cm^{-1}; δ($CDCl_3$) 2.90 (4 H, m), 3.73 (2 H, s), 3.98 (2 H, s), 6.76 (1 H, d, *J* 5.4 Hz), 7.30 (5 H, s), and 7.45 (1 H, d, *J* 5.4 Hz); $\lambda_{max.}$(EtOH) 271 nm (ε 9 700 dm^3 mol^{-1} cm^{-1}).

5-(p-*Tolylsulphonyl*)-4,5,6,7-*tetrahydro*-8H-*thieno*[3,2-c]-*azepin*-8-*one* (**17b**).—A suspension of the carboxylic acid (**16b**) (78.2 g, 230 mmol) and phosphorus pentachloride (71.8 g, 300 mmol) in dry benzene (1 600 ml) was stirred at room temp-

erature for 2 h until it became clear. It was then repeatedly co-distilled with benzene at 30 °C under reduced pressure to remove the phosphoryl chloride. To a stirred and cooled solution of the residue in dry benzene (1 500 ml) in an ice-bath was added slowly tin(IV) chloride (90 g, 346 mmol) through a syringe. After being stirred for 17 h at room temperature, the reaction mixture was hydrolysed by careful addition of crushed ice and hydrochloric acid (2M). The organic layer was then separated, dried ($MgSO_4$), and evaporated under reduced pressure to give the 5-(*p*-tolylsulphonyl) ketone (**17b**) (65.1 g, 88%), which was recrystallized from ethanol, m.p. 116—117.5 °C (Found: C, 56.05; H, 4.6; N, 4.2. $C_{15}H_{15}NO_3S_2$ requires C, 56.05; H, 4.7; N, 4.4%); $\nu_{max.}$(Nujol) 1 625 cm^{-1} (C=O); δ($CDCl_3$) 2.40 (3 H, s), 2.92 (2 H, t, *J* 5.3 Hz), 3.58 (2 H, t, *J* 5.3 Hz), 4.66 (2 H, s), 6.87 (1 H, d, *J* 5.3 Hz), 7.22 (2 H, d, *J* 8.3 Hz), 7.50 (1 H, d, *J* 5.3 Hz), and 7.60 (2 H, d, *J* 8.3 Hz); $\lambda_{max.}$(EtOH) 271 nm (ε 10 960 dm^3 mol^{-1} cm^{-1}).

5-*Ethoxycarbonyl*-4,5,6,7-*tetrahydro*-8H-*thieno*[3,2-c]*azepin*-8-*one* (**18**).—A solution of the 5-benzyl ketone (**17a**) (41 mg, 0.16 mmol) and ethyl chloroformate (78 mg, 0.72 mmol) in benzene (10 ml) was refluxed for 14 h after which the volatile compounds were evaporated off under reduced pressure and the residue purified by m.p.l.c. [hexane–ethyl acetate (4:1 v/v)]. The 5-ethoxycarbonyl ketone (**18**) (29 mg, 76%) was obtained as colourless liquid, b.p. 135—140 °C/4 mmHg (Found: C, 55.1; H, 5.7; N, 5.8. $C_{11}H_{13}NO_3S$ requires C, 55.2; H, 5.5; N, 5.85%).

4,5,6,7-*Tetrahydro*-8H-*thieno*[3,2-c]*azepin*-8-*one* (**19**).—A mixture of the 5-(*p*-tolylsulphonyl) ketone (**17b**) (1.0 g, 3.2 mmol) and PPA (11.0 g) was heated at 80 °C for 30 h under a nitrogen atmosphere. After cooling, crushed ice was added to the mixture, which was then made alkaline with aqueous potassium hydroxide and extracted with dichloromethane. The organic layer was extracted with dilute hydrochloric acid (2M). The acidic layer was washed with ether, again basified with aqueous potassium hydroxide, and extracted with dichloromethane. The extract was dried ($MgSO_4$) and evaporated to give the amino ketone (**19**) (290 mg, 56%), which was purified by column chromatography (ether) on silica gel, m.p. 54—56 °C (ethanol–water) (Found: C, 57.6; H, 5.5; N, 8.4. C_8H_9NOS requires C, 57.5; H, 5.4; N, 8.4%).

N-*Ethoxycarbonylation of the Amino Ketone* (**19**).—To a stirred solution of the amino ketone (**19**) (103 mg, 0.62 mmol) and triethylamine (65 mg, 0.64 mmol) in ethanol (25 ml), was added ethyl chloroformate (70 mg, 0.64 mmol). After 3 h at room temperature the reaction mixture was evaporated, the residue dissolved in ether, and the ether solution washed with water, dried ($MgSO_4$), and evaporated under reduced pressure to give the ester (**18**) (134 mg, 90%).

7-*Bromo*-5-(p-*tolylsulphonyl*)-4,5,6,7-*tetrahydro*-8H-*thieno*-[3,2-c]*azepin*-8-*one* (**20**).—The *N*-(*p*-tolylsulphonyl) ketone (**17b**) (40 g, 125 mmol) and pyridinium hydrobromide perbromide (40 g, 125 mmol) in glacial acetic acid (1 300 ml) were stirred and heated at 50—60 °C for 12 h. The reaction mixture was then cooled, the acetic acid removed under reduced pressure, and the residue extracted with chloroform. The organic layer was washed successively with dilute hydrochloric acid (1M) and saturated aqueous sodium hydrogen carbonate, and dried ($MgSO_4$). Evaporation under reduced pressure afforded the 7-*bromo ketone* (**20**) (38.7 g, 78%) as colourless needles (ethanol), m.p. 150—151 °C (Found: C, 45.1; H, 3.4; N, 3.4. $C_{15}H_{14}BrNO_3S_2$ requires C, 45.0; H, 3.5; N, 3.5%); $\nu_{max.}$(Nujol) 1 640 cm^{-1} (C=O); δ($CDCl_3$) 2.43 (3 H, s), 3.39 (1 H, dd, *J* 14.9 and 10.6 Hz), 4.15 (1 H, ddd, *J* 14.9, 5.1, and 1.3 Hz), 4.30 (1 H, d, *J* 16.9 Hz), 4.87 (1 H, dd, *J* 10.6 and 5.4 Hz), 4.93 (1 H, dd, *J* 16.9 and 1.3 Hz), 6.92 (1 H, d, *J* 5.3 Hz), 7.34 (2 H, d, *J* 7.5 Hz), 7.64 (1 H, d, *J* 5.3 Hz), and 7.70 (2 H, d, *J* 7.5 Hz); $\lambda_{max.}$(EtOH) 229 (ε 13 800 dm^3 mol^{-1} cm^{-1}) and 283 nm (8 910).

6,7-*Dihydroazirino*[1,2-a]*thieno*[2,3-d]*pyridin*-8-*one* (**22**).—The 7-bromo ketone (**20**) (30 g, 75 mmol) and PPA (500 g) were stirred and heated together at 80 °C under a nitrogen atmosphere for 30 h. After being cooled, crushed ice was added to the mixture, which was then made alkaline with potassium hydroxide and extracted with chloroform. Evaporation of the dried extract under reduced pressure left an oil which was purified by column chromatography on silica gel [chloroform–methanol (25:1 v/v)] and crystallized from methanol to give the tricyclic *ketone* (**22**) (7.8 g, 63%) as colourless needles, m.p. 63—65 °C (Found: C, 58.3; H, 4.25; N, 8.4. C_8H_7NOS requires C, 58.2; H, 4.3; N, 8.5%); $\nu_{max.}$(Nujol) 1 630 cm^{-1} (C=O); δ($CDCl_3$) 1.83 (1 H, d, *J* 3.0 Hz), 2.42 (1 H, d, *J* 6.2 Hz), 2.85 (1 H, dd, *J* 6.2 and 3.0 Hz), 4.42 (2 H, s), 6.85 (1 H, d, *J* 5.0 Hz), and 7.68 (1 H, d, *J* 5.0 Hz); $\lambda_{max.}$(EtOH) 255sh (ε 6 920 dm^3 mol^{-1} cm^{-1}) and 281 nm (9 770).

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