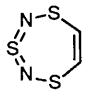
# Organic Heterocyclothiazenes. Part 14.[1] Aminotrithiadiazepines and Trithiadiazepyne

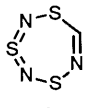
**M. John Plater and Charles W. Rees**
*Department of Chemistry, Imperial College of Science, Technology and Medicine, London SW7 2AY, UK*

Amino derivatives of the trithiadiazepine ring are described for the first time, as moderately stable crystalline solids. They are readily formed from the monobromo derivative by nucleophilic substitution under remarkably mild conditions, though only *via* the 6,7-didehydrotrithiadiazepine (trithiadiazepyne) intermediate. The aryne mechanism is established by hydrogen–deuterium exchange and by trapping and competitive trapping of the aryne, generated from chloro-, bromo-, and iodotrithiadiazepine, with dienes and nucleophiles.

In this series of papers we have described a new family of heterocyclic compounds, on the border of organic and inorganic chemistry, which are characterised by an unusually high proportion of nitrogen and sulphur heteroatoms. These compounds were initially derived, both conceptually and experimentally, from tetrasulphur tetranitride and related inorganic compounds with rings composed wholly of sulphur and nitrogen atoms. Organic heterocyclic rings with a high proportion of heteroatoms are relatively rare; they are usually inaccessible, and when they are known they tend to be unstable. It occurred to us that a possible general approach to more stable compounds of this type would be to start with stable rings composed entirely of 'heteroatoms' and to introduce one or two carbon atoms into them. In this way we discovered these organic heterocyclothiazenes as stable, planar, delocalised, aromatic systems. Trithiadiazepine **1** and trithiatriazepine **2** are typical; they are electron rich with $10\pi$ electrons delocalised over the seven ring atoms. They are formed by the cycloaddition of alkynes to $S_4N_4$,[2] and the parent trithiadiazepine **1** has been synthesised independently.[3] The delocalised structures proposed are based on spectroscopy and X-ray structure determination, and are supported by their chemical reactivity.[4,5] Thus trithiadiazepine **1** readily undergoes electrophilic substitution to give mono- and di- nitro and bromo derivatives, and this provides ready access to trithiadiazepines bearing electron-withdrawing groups. We also wished to obtain derivatives with electron releasing groups, notably $NH_2$ and OH, because of their key role in synthesis and their interest as strongly electron releasing groups on the $\pi$-excessive ring. We have previously described the amino derivatives of trithiatriazepine **2**,[6] and in this paper we report the formation of the corresponding derivatives of trithiadiazepine **1** by an elimination–addition mechanism, and establish 6,7-didehydrotrithiadiazepine (trithiadiazepyne) **3** as the key reaction intermediate.



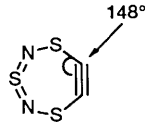
**1**



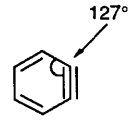
**2**

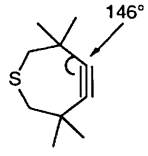
## Discussion

*Aminotrithiadiazepines.*—Electron-releasing substituents are commonly introducted into aromatic systems by nucleophilic substitution and this process was therefore important to us, particularly when we failed, after many attempts, to reduce 6-nitrotrithiadiazepine to the primary amine.[4] Unfortunately, standard nucleophilic displacement of halogen from the monobromo derivative appeared unpromising since the trithiadiazepine ring is not activated to nucleophilic attack and it is also rather unstable towards alkaline conditions.[4] However, inspection of the seven-membered ring with its three large sulphur atoms suggested that an elimination–addition mechanism, *via* the hetaryne **3**, might be possible.[7] This idea was encouraged by the slightly elongated shape of the trithiadiazepine ring, as shown by X-ray diffraction, and the C–C–S internal bond angle (148°) calculated for the aryne **3**[8] which is much greater than the analogous angle calculated for benzyne (127°), and is close to the measured angle (146°) for the isolable cycloalkyne **4**.[9]



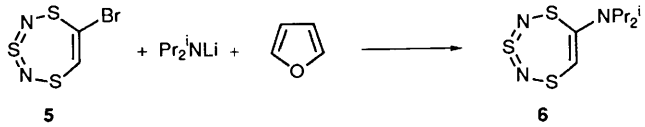

**3**



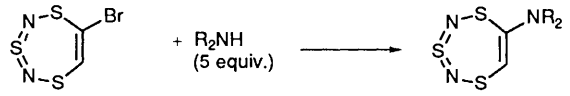

**4**

Some preliminary experiments had suggested that the hetaryne **3** could be generated from 6,7-dibromotrithiadiazepine with BuLi at low temperature.[7] In the presence of an excess of furan or 2,5-dimethylfuran the corresponding aryne cycloadducts were formed though only in poor yield. We reasoned that treatment of 6-bromotrithiadiazepine **5** with a milder, hindered base might effect the elimination of hydrogen bromide to generate trithiadiazepyne **3** in a cleaner reaction. 6-Bromotrithiadiazepine was treated with lithium diisopropylamide in the presence of furan in tetrahydrofuran (THF) at −78 °C. A slow reaction did occur but none of the furan–aryne cycloadduct was formed. However, a high yield of the diisopropylamino derivative **6**, the first amine of this ring system, was formed as a stable, pale yellow crystalline solid. To optimise its yield a series of identical experiments were set up and quenched with acetic acid after different times to see how long the reaction took to go to completion at −78 °C; all of the bromotrithiadiazepine **5** was consumed in *ca.* 6 h. However, we noticed that even after quenching with acetic acid the reaction continued to give more product. From this it was deduced that the amine lithio derivatives were not essential and the amines themselves could be used.

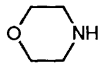



**5** **6**

Primary and secondary aliphatic amines reacted with 6-bromotrithiadiazepine **5** in THF at room temperature to give




5

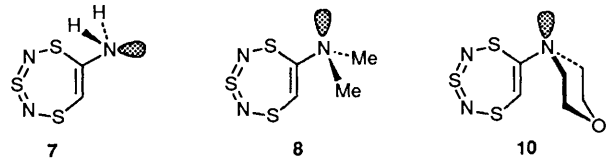
| $R_2NH$: | $Pr^i_2NH$ | $NH_3$ | $Me_2NH$ | $PhCH_2NH_2$ |  | PhNHLi |
|---|---|---|---|---|---|---|
| Product: | **6** | **7** | **8** | **9** | **10** | **11** |
| % Yield | 69 | 86 | 71 | 78 | 86 | 70 |

**Scheme 1**

the corresponding aminotrithiadiazepines **6**–**10** in the yields shown (Scheme 1); 2-methylaziridine reacted similarly. Aniline itself did not react but its *N*-lithio derivative did, to give 6-anilinotrithiadiazepine **11**. Most remarkable was the reaction with dry ammonia gas to form 6-aminotrithiadiazepine **7**, which took only 20 min to go to completion on a 0.5 g scale. Although the primary and particularly the secondary amines are sensitive compounds, they have all been fully characterised. They all show an IR absorption close to 1150 $cm^{-1}$ and a long wavelength UV absorption around 330 nm. These values are very similar to those of trithiadiazepine **1** itself.

In contrast to the shielding effect of electron-releasing groups on *ortho* and *para* protons in benzenoid systems, here the trithiadiazepine ring protons of the amino derivatives have almost identical chemical shifts ($\delta_H$ = 7.56–7.90) to that of the parent **1** ($\delta_H$ = 7.76). These similarities in spectroscopic properties suggest there is little interaction between the amine lone pair of electrons and the delocalised π system of the ring.

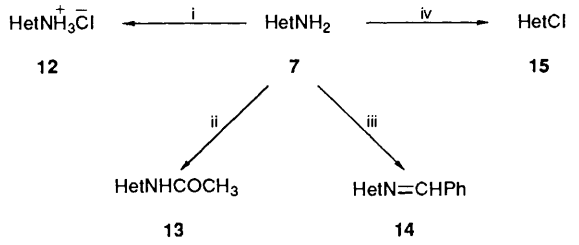
X-Ray crystal structures of the amino- **7**, dimethylamino- **8** and morpholino-trithiadiazepines **10** were obtained.[10] In all three, the amino groups are tetrahedral and are twisted out of the plane of the ring so that the nitrogen lone pair is orthogonal to the π system, as shown below. For the dimethylamino **8** and morpholino **10** compounds the nitrogen lone pair is antiperiplanar to the less polarisable carbon–carbon bond. Hence the bond lengths of the trithiadiazepine ring are undistorted and identical with those of the parent itself. The lone pair of the primary amino group is situated antiperiplanar to the lower energy, polarisable carbon–sulphur bond. Overlap between the nitrogen lone pair and the σ* antibonding molecular orbital of the carbon–sulphur bond should elongate the carbon–sulphur bond slightly. This ground state stereoelectronic effect is observed with a slight lengthening of this bond with some distortion to the remaining ring angles. Normally the amino group of an aromatic amine, such as in aniline, is conjugated with the π-system; presumably this is disfavoured here because of the electron rich nature of the π-system, and the exocyclic nitrogen is acting simply as an inductively electron-withdrawing group.



**7** **8** **10**

6-Aminotrithiadiazepine **7** is best stored in a dilute dichloromethane solution in the cold; this can be concentrated to a solid prior to use by removal of the solvent *in vacuo* at room temperature. Heating causes rapid decomposition of the amine. Successful reactions of the primary amine are summarised in Scheme 2.

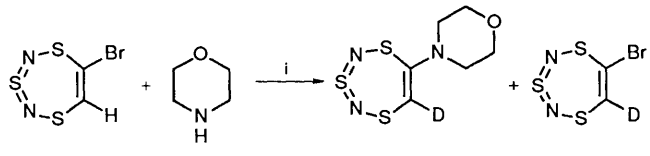
The amine is acid sensitive and is not stable in acetic acid although the hydrochloride salt **12** can be formed by precipitation from ether under anhydrous conditions. Derivatives **13** and **14** are stable crystalline solids. Attempted bromination using *N*-bromosuccinimide in acetonitrile and nitration using nitronium tetrafluoroborate or copper(II) nitrate decomposed the amine, probably because of its acid sensitivity. Diazotisation of the amine proved difficult although a low yield of the chloro compound **15** was isolated, presumably formed *via* the diazonium salt.




**12** **7** **15** **13** **14**

**Scheme 2** *Reagents:* i, dry HCl, $Et_2O$; ii, $Ac_2O$, $CH_2Cl_2$; iii, PhCHO, $CH_3CN$, 20 °C; iv, AmONO, HCl, THF

*Trithiadiazepyne* **3**.—No furan–aryne cycloadduct was detected in any of the above reactions and it seemed unlikely that an elimination–addition mechanism was operating since such weak bases were being used. The reaction conditions, *e.g.* dry ammonia gas in THF at room temperature, were extremely mild for the displacement of bromine from an electron-rich heteroaromatic compound, by whatever mechanism. However 6,7-dibromotrithiadiazepine and the 7-bromo derivative of trithiatriazepine **2**[6] were completely inert to the amines used under the reaction conditions, and thus the possibility of elimination of hydrogen bromide from the monobromide **5** had to be considered. The acidity of the proton in **5** was, therefore, investigated by deuterium exchange, using morpholine as the base. With morpholine and an excess of $D_2O$ deuteriation was extensive in the product **16** and also in the recovered bromide **5** (Scheme 3). Deuteriated bromotrithiadiazepine was prepared

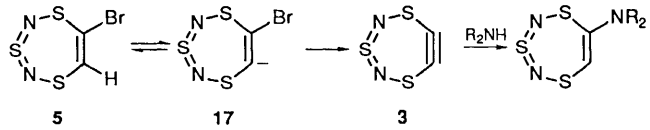



**5** (5 equiv.) **16** (90%) (80%)

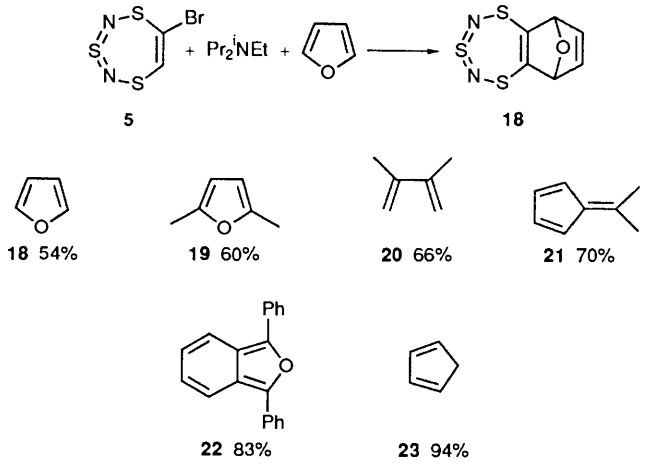
**Scheme 3** *Reagents:* i, $D_2O$, THF, 20 °C

by mercuriation of bromotrithiadiazepine[11] followed by treatment with concentrated DCl; when it was treated with an excess of morpholine at room temperature the product and recovered starting material were extensively de-deuteriated (> 90% at 70% reaction). These deuteriation experiments clearly suggested that an elimination–addition mechanism could be operating. The parent trithiadiazepine **1** was also readily deuteriated with a tertiary base and $D_2O$ in THF, as was 6-nitrotrithiadiazepine; 6-morpholinotrithiadiazepine **10** did not undergo hydrogen–deuterium exchange.

The bromo carbanion **17** could be formed rapidly and reversibly and, by analogy with benzyne formation, would eliminate bromide to form the hetaryne **3** to which amines or amide ions could add nucleophilically. The absence of the furan–aryne cycloadduct could result from the greater reactivity of the amines (and amide ions) over furan in intercepting the aryne.



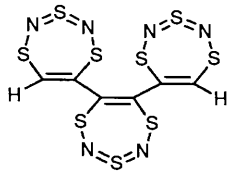

**5** **17** **3**




Scheme 4

Cycloaddition to the aryne should be facilitated by replacing the above amines (Scheme 1) with a hindered non-nucleophilic amine. We chose Hünig's base, *N,N*-diisopropylethylamine. When 6-bromotrithiadiazepine **5** was treated with this base and furan in THF at room temperature the cycloadduct **18** was indeed formed, but the reaction was slow, requiring several days for completion. We noticed that the $D_2O$ exchange reactions, catalysed by Hünig's base, were much faster than the cycloaddition, and $D_2O$ and $H_2O$ were found to have a marked accelerating effect on the latter. Too much water caused decomposition of the bromo compound but fortunately methanol had the same accelerating effect without causing decomposition, and dry methanol could be used as solvent. The reactions were much cleaner and faster in methanol and were complete in 5–10 min at room temperature with 2 or 3 equiv. of Hünig's base; this became a standard method for generating the aryne. The aryne could be trapped in methanol with a variety of electron rich dienes in the yields shown (Scheme 4). With the reactive diene, cyclopentadiene, the trapping is nearly quantitative. In the absence of the base no reaction occurred between the bromo compound **5** and the dienes. Indeed trithiadiazepine itself has previously been shown to be inert towards a range of dienes and dienophiles under forcing conditions.[4]

In the absence of a diene the reaction was complex. A trace of 6-methoxytrithiadiazepine was formed but the aryne dimer and trimer were not. However, a small quantity of a trimer reduced with two hydrogen atoms was isolated (11%). This showed a molecular ion in the mass spectrum and sequential fragments for the loss of 46(NS), and its IR and UV spectra were characteristic of trithiadiazepine rings. The compound was tentatively assigned structure **24**. Transition metals have the ability to stablise benzynes and strained cycloalkynes.[9] We hoped that treatment of the bromo compound **5** with a base in the presence of a transition metal might lead to a metal aryne complex. Generation of trithiadiazepyne **3** in methanol or acetonitrile using Hünig's base in the presence of palladium chloride, octacarbonylcobalt, or dicarbonylcyclopentadienylcobalt gave complex reaction mixtures from which no products could be isolated. Traces of the 'trimer' **24** were detected by TLC.



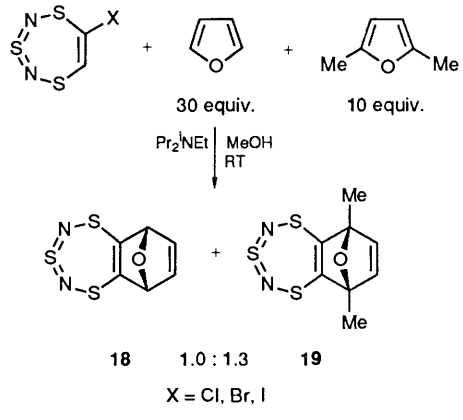
**24**

The aryne mechanism now seemed more reasonable. It was also supported by formation of the anilino derivative **11** (76%) from the bromo compound with Hünig's base and aniline in THF. Aniline itself did not react. The stronger base is needed to generate the aryne which is then intercepted by aniline. Interestingly, this reaction proceeded at a reasonable rate in THF, in contrast with the reaction with furan as the aryne trap.

No 6-methoxytrithiadiazepine was formed from the cycloadditions in methanol. Presumably the aryne is not sufficiently electrophilic to be attacked by methanol; similarly the strained cycloalkyne **4** does not undergo nucleophilic addition of methanol.[9] Sodium methoxide in methanol reacted with 6-bromotrithiadiazepine **5** to form the methoxytrithiadiazepine, but only in low yield (~30%). In view of this a cycloaddition was performed with sodium methoxide as the base. A dilute solution of 2.5 equiv. of sodium methoxide in methanol, slowly added to the bromo compound and a diene over 30 min, gave improved yields of cycloadducts [**18** (73%), **19** (75%) and **22** (92%)] compared to those with Hünig's base, together with cycloadducts from 2-methylfuran (79%) and 6-dimethylaminofulvene (25%). This is the preferred method for generation and trapping of the hetaryne with electron-rich dienes.

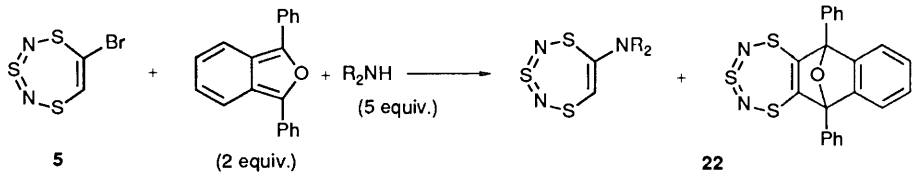
*The Hetaryne Mechanism: Competition Experiments.*—In contrast with nucleophilic aromatic substitution generally, where elimination–addition mechanisms *via* aryne intermediates are of relatively minor importance, the aryne pathway proposed here appears to be the only route for nucleophilic substitution in trithiadiazepines. We therefore considered it important to establish the mechanism more firmly, and to explain why the reaction proceeds under such mild conditions. So we investigated its response to structural changes in the aryne precursor and the diene, and have performed various competition experiments. Whilst the high symmetry of the hetaryne **3** presumably increases its stability, the absence of ring substituents precludes one of the easier ways of establishing the presence of an (unsymmetrical) aryne.

We first studied the competition between furan and 2,5-dimethylfuran for the aryne generated from three precursors, the chloro-, bromo-, and iodo-trithiadiazepines (Scheme 5). The




Scheme 5

molar ratio of the two furans was adjusted to give approximately equal amounts of the two cycloadducts as shown. The ratio of the aryne adducts from each precursor was carefully determined by $^1H$ NMR on the total reaction product. The three ratios were found to be identical within experimental error, and are actually closer than related figures for benzyne cycloadditions.[12] Thus the *same* species is presumably undergoing the Diels–Alder reactions in each case, and the hetaryne **3** seems to be the only reasonable candidate. Interestingly the




5 (2 equiv.) 22

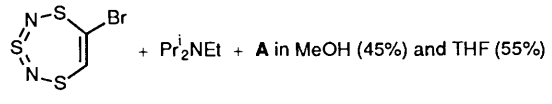
| $R_2NH$ = | | |
|---|---|---|
| morpholine | 74% | 3% |
| diisopropylamine | 54% | 11% |
| 2, 2, 6, 6-tetramethylpiperidine | 0% | 76% |

**Scheme 6**

chloro and iodo compounds reacted more slowly than the bromide **5**. Presumably the iodotrithiadiazepine carbanion is formed less readily than **17** because of the weaker inductive effect of iodine, whilst the chlorotrithiadiazepine carbanion forms readily but chlorine is a poorer leaving group than bromine.

We next studied the competition between a highly reactive, high-yielding diene, 1,3-diphenylisobenzofuran, and three amines of widely differing nucleophilicity, with the results shown in Scheme 6. The strong nucleophile morpholine gave almost exclusively the morpholino derivative, the weak nucleophile diisopropylamine gave the diisopropylamino derivative together with some isobenzofuran cycloadduct, and the non-nucleophilic 2,2,6,6-tetramethylpiperidine gave almost exclusively the cycloadduct. With the much less reactive diene furan, diisopropylamine gave only the amine product, and tetramethylpiperidine gave much less cycloadduct (15%). Control experiments established that the cycloadduct was not destroyed by the amines used. These results thus require the involvement of a reactive intermediate that can be intercepted by both Diels–Alder reactions and nucleophilic additions.

On the basis of an aryne mechanism the rate of cycloadduct formation should be independent of the nature of the diene. With this in mind we measured, qualitatively, the rate of consumption of the bromo compound **5** in the absence and presence of dienes, under standard conditions (Scheme 7). The




5

| A | | Time for consumption of 5 |
|---|---|---|
| — | | 9 h |
| 1,3-diphenylisobenzofuran | (1 equiv.) | 2 h |
| 2,5-dimethylfuran | (4 equiv.) | 3.5 h |
| $Pr^i_2NH^+$ Et $Br^-$ | (10 equiv.) | 55 h |
| 1,3-diphenylisobenzofuran + $Pr^i_2NH^+$ Et $Br^-$ | (1 equiv.) (10 equiv.) | 2.5 h |

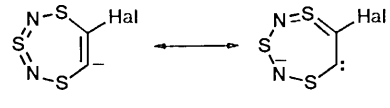
**Scheme 7**

solvent mixture of methanol (45%) and THF (55%) was selected to give convenient reaction rates, and the times shown are for disappearance of the starting bromide, which could be clearly monitored by thin layer chromatography. The reaction rates were, to our surprise, influenced by the dienes. In the absence of a diene it took 9 h for the bromo compound to be decomposed by 5 equiv. of Hünig's base. However, with 1,3-diphenylisobenzofuran present this time was reduced to 2 h and with 2,5-dimethylfuran it was reduced to 3.5 h. This can be explained by assuming that formation of the aryne is reversible, *i.e.* bromide ion can attack the aryne to reform the bromo carbanion **17**. With the diene present this effect is swamped out. If bromide ion can attack the aryne then the decomposition rate should be retarded by adding bromide. Indeed 10 equiv. of Hünig's base hydrobromide increased the time of consumption of bromotrithiadiazepine to 55 h. With 1,3-diphenylisobenzofuran and excess of Hünig's base hydrobromide this effect is swamped out and the consumption time reverts to 2.5 h.

If the aryne does react with bromide ion it should react similarly with iodide; this was demonstrated by ready conversion of the bromo compound **5** into the corresponding iodo compound (70%) with tetrabutylammonium iodide in methanol at room temperature. The iodo compound is also formed when **5** is treated with Hünig's base in the presence of the quaternary iodide, but the reaction is less clean and the yield is lower (51%) since Hünig's base also reacts with the iodotrithiadiazepine.

All of these results lead most reasonably to an overall reaction scheme where the aryne **3** is formed reversibly *via* carbanion **17** and then reacts irreversibly with dienes and most nucleophiles.

The most striking aspect of this mechanism is the ready formation of the carbanion, presumably resulting from its relatively high stability. Why should it be so stable? One possibility is some rehybridisation of the polarisable π-system which can be represented by the extreme resonance form shown **25**. The negative charge is extensively delocalised onto the heteroatoms with a carbenoid-like contribution on carbon. This is supported by the acidity of related five-membered heteroaromatics such as thiazoles[13] where, upon alkylation or protonation of the ring nitrogen, the analogous carbanions show electrophilic as well as nucleophilic behaviour.[14] The carbanion will be stablised by the adjacent sulphur atom, and it is also antiperiplanar to a polarisable carbon–sulphur and sulphur–nitrogen bond. There may be a stabilising overlap between the carbanion and the σ* antibonding orbitals of these two bonds. The slight change in geometry which occurs for stabilising antiperiplanar interactions could be accommodated by the trithiadiazepine ring which has some flexibility owing to the three large diffuse sulphur atoms. In water and, especially, methanol the rate of aryne formation is greatly increased, so the carbanion may also be stabilised by hydrogen bonding, though hydrogen-bonding solvation of the departing bromide and the ring heteroatoms, thus activating proton loss, could also contribute.




25

We have already indicated that the measured shape of the trithiadiazepine ring and the calculated shape of its didehydro derivative are compatible with a relatively stable hetaryne, and we believe that this is now firmly established as a synthetically

useful reactive intermediate. Further aspects of its chemistry will be described later.

## Experimental

For general points see earlier Parts of the series.

### *Aminotrithiadiazepines*

6-*Diisopropylamino*-1,3λ⁴δ²,5,2,4-*trithiadiazepine* **6**.—(i) A solution of lithium diisopropylamide (LDA) in THF (15 ml) was prepared by treating diisopropylamine (58 mg, 0.57 mmol) with BuLi (1.6 mol $dm^{-3}$; 0.30 ml, 0.48 mmol) at −78 °C. The mixture was stirred at low temperature for 20 min followed by the slow addition over 2 min of 6-bromotrithiadiazepine (100 mg, 0.44 mmol) in THF (3 ml). After being stirred at −78 °C for 6 h the mixture was allowed to warm to room temperature, concentrated under reduced pressure and chromatographed on silica. Elution with light petroleum gave the *title compound* (89 mg, 82%) as a pale green solid, m.p. 30–31 °C (after Kugelrohr distillation at 95 °C: 1 mmHg) (Found: C, 38.4; H, 6.0; N, 16.2. $C_8H_{15}N_3S_3$ requires C, 38.6; H, 6.0; N, 16.9%); $\lambda_{max}$(EtOH)/nm 225 (log ε 4.17) and 330 (3.83); $\nu_{max}(CHCl_3)/cm^{-1}$ 1139s; $\delta_H$(90 MHz; $CDCl_3$) 1.15 (12 H, d, 4 × Me), 3.58 (2 H, m, CH), and 7.73 (1 H, s); $\delta_C$(62.9 MHz; $CDCl_3$) 21.9 (Me), 52.2 (CH), 129.6 and 150.4; *m/z* (150 °C) 249 ($M^+$, 26%), 203 ($M^+$ − NS,51) and 43 ($Me_2CH$, 100).

(ii) 6-Bromotrithiadiazepine (30 mg, 0.13 mmol) in THF (6 ml) was treated with diisopropylamine (0.09 ml, 0.65 mmol) at room temperature. The reaction mixture was stirred for 2 h, concentrated under reduced pressure and chromatographed on silica. Elution with light petroleum gave the title compound (23 mg, 70%) identical with that previously described.

6-*Amino*-1,3λ⁴δ²,5,2,4-*trithiadiazepine* **7**.—6-Bromotrithiadiazepine (100 mg, 0.44 mmol) in THF (50 ml) was treated with a stream of dry ammonia gas for 20 min at 0 °C. The solvent was then removed under reduced pressure and the product chromatographed on silica. Elution with dichloromethane gave the *title compound* (62 mg, 86%) as a yellow solid. The product was crystallised from light petroleum–dichloromethane (75:25) as fawn crystals, m.p. 56–57 °C (Found: C, 14.6; H, 1.7; N, 25.3. $C_2H_3N_3S_3$ requires C, 14.6; H, 1.8; N, 25.45%); $\lambda_{max}$(EtOH)/nm 225 (log ε 3.86) and 324 (3.53); $\nu_{max}(CCl_4)/cm^{-1}$ 3380w, 3320w and 1150vs; $\delta_H$(250 MHz; $CDCl_3$) 7.56 (1 H, s) and 3.64 (2 H, s); *m/z* (120 °C) 165 ($M^+$, 100%), 124 (15) and 119 ($M^+$ − NS, 47).

6-*Dimethylamino*-1,3λ⁴δ²,5,2,4-*trithiadiazepine* **8**.—6-Bromotrithiadiazepine (50 mg, 0.22 mmol) in THF (10 ml) was cooled to 0 °C and treated with an aqueous dimethylamine solution (40% w/v; 2 ml). After being stirred for 20 min at 0 °C the solution was concentrated and chromatographed on silica. Elution with dichloromethane gave the *title compound* as a green solid (33 mg, 76%), m.p. 75–76 °C (from methanol) (Found: C, 24.8; H, 3.5; N, 21.5. $C_4H_7N_3S_3$ requires C, 24.9; H, 3.6; N, 21.8%); $\lambda_{max}$(EtOH)/nm 225 (log ε 3.98) and 330 (3.77); $\nu_{max}(CHCl_3)/cm^{-1}$ 1147vs; $\delta_H$(90 MHz; $CDCl_3$) 2.90 (6 H, s) and 7.72 (1 H, s); *m/z* (100 °C) 193 ($M^+$, 100%) and 147 ($M^+$ − NS, 95).

6-*Benzylamino*-1,3λ⁴δ²,5,2,4-*trithiadiazepine* **9**.—6-Bromotrithiadiazepine (30 mg, 0.13 mmol) in acetonitrile (6 ml) at 0 °C was treated with benzylamine (0.073 ml) for 4 h. The product was concentrated under reduced pressure and chromatographed on silica. Elution with dichloromethane gave the *title compound* (26 mg, 78%) as a yellow solid, m.p. 62–63 °C (from acetone). The product was best purified by washing with cold methanol (Found: C, 42.4; H, 3.4; N, 16.4. $C_9H_9N_3S_3$ requires C, 42.4; H, 3.5; N, 16.5%); $\lambda_{max}$(EtOH)/nm 327 (log ε 3.71); $\nu_{max}(CCl_4)/cm^{-1}$ 3356w and 1149vs; $\delta_H$(90 MHz; $CDCl_3$) 3.65 (1 H, s), 4.35 (2 H, s, $CH_2$), 7.33 (5 H, br) and 7.55 (1 H, s); *m/z* (100 °C) 255 ($M^+$, 9.2%), 209 ($M^+$ − NS, 4.4) and 91 ($PhCH_2$, 100).

6-*Morpholino*-1,3λ⁴δ²,5,2,4-*trithiadiazepine* **10**.—6-Bromotrithiadiazepine (50 mg, 0.22 mmol) in THF (10 ml) was treated with morpholine (0.1 ml, 1.1 mmol) at room temperature. After being stirred for 8 h the reaction mixture was concentrated and chromatographed on silica. Elution with dichloromethane gave the *title compound* (45 mg, 86%) as a colourless solid, m.p. 132–133 °C (from acetone) (Found: C, 30.4; H, 3.8; N, 17.6. $C_6H_9N_3OS_3$ requires C, 30.6; H, 3.8; N, 17.9%); $\lambda_{max}$(EtOH)/nm 233 (log ε 4.08) and 334 (3.92); $\nu_{max}(CHCl_3)/cm^{-1}$ 1149vs; $\delta_H$(250 MHz; $CDCl_3$) 3.10 (4 H, m), 3.80 (4 H, m) and 7.74 (1 H, s); $\delta_C$(62.9 MHz; $CDCl_3$) 55.9 ($CH_2N$), 67.4 ($CH_2O$), 123.9 and 156.9; *m/z* (110 °C) 235 ($M^+$, 90%), 189 ($M^+$ − NS, 100) and 86 (72).

6-*Anilino*-1,3λ⁴δ²,5,2,4-*trithiadiazepine* **11**.—(i) Aniline (0.026 ml, 0.28 mmol) in THF (8 ml) was cooled to −78 °C and treated with BuLi (1.6 mol $dm^{-3}$, 0.15 ml in THF, 0.24 mmol). The mixture was stirred at −78 °C for 20 min after which a solution of 6-bromotrithiadiazepine (50 mg, 0.22 mmol) in THF (2 ml) was added to it; it was then kept at −78 °C for 3 h. After this, the mixture was allowed to warm to room temperature and then chromatographed on silica. Elution with dichloromethane gave the *title compound* (37 mg, 70%) as pale brown crystals, m.p. 94–95 °C (from chloroform). The product was best purified by washing with cold methanol (Found: C, 39.8; H, 2.8; N, 17.45. $C_8H_7N_3S_3$ requires C, 39.8; H, 2.9; N, 17.4%); $\lambda_{max}$(EtOH)/nm 239 (log ε 3.94) and 325 (3.41); $\nu_{max}(CCl_4)/cm^{-1}$ 3409w and 1152s; $\delta_H$(90 MHz; $CDCl_3$) 5.82 (1 H, br s, NH), 6.80 (3 H, m, Ph), 7.20 (2 H, m, Ph) and 7.90 (1 H, s); *m/z* (120 °C) 241 ($M^+$, 100%), 195 ($M^+$ − NS, 33) and 77 (Ph, 37).

(ii) 6-Bromotrithiadiazepine (100 mg, 0.44 mmol) in THF (15 ml) was treated with aniline (200 mg, 2.2 mmol) and Hünig's base (280 mg, 2.2 mmol) for 48 h at room temperature. The solvent was then removed under reduced pressure and the residue chromatographed on silica. Dichloromethane eluted 6-anilino-1,3λ⁴δ²,5,2,4-trithiadiazepine **11** (80 mg, 76%) identical with that previously described.

6-(2,2,6,6-*Tetramethylpiperidino*)-1,3λ⁴δ²,5,2,4-*trithiadiazepine*.—6-Bromotrithiadiazepine (50 mg, 0.22 mmol) in THF (6 ml) was treated with tetramethylpiperidine (308 mg, 106 mmol) at room temperature. The mixture was stirred for 16 h after which it was evaporated under reduced pressure and the residue chromatographed on silica. Elution with light petroleum gave the *title compound* (41 mg, 40%) as a colourless solid, m.p. 88–89 °C (from acetone) (Found: C, 46.0; H, 6.5; N, 14.5. $C_{11}H_{19}N_3S_3$ requires C, 45.7; H, 6.6; N, 14.5%); $\lambda_{max}$(EtOH)/nm 225 (log ε 4.05) and 335 (3.79); $\nu_{max}(CCl_4)/cm^{-1}$ 1176 vs; $\delta_H$(250 MHz; $CDCl_3$) 1.05 (6 H, s, 2 × Me), 1.60 (6 H, m, 3 × $CH_2$) and 7.80 (1 H, s); *m/z* (160 °C) 289 ($M^+$, 6%) and 243 ($M^+$ − NS, 70%).

2-*Methylaziridino*-1,3λ⁴δ²,5,2,4-*trithiadiazepine*.—6-Bromotrithiadiazepine (100 mg, 0.44 mmol) in THF (10 ml) was treated with 2-methylaziridine (125 mg, 2.2 mmol). The mixture was stirred at room temperature for 5 h after which it was evaporated under reduced pressure and the residue chromatographed on silica. Light petroleum–dichloromethane (50:50) eluted the *title compound* (59 mg, 65%) as an oil (Found: C, 29.4; H, 3.3; N, 20.4. $C_5H_7N_3S_3$ requires C, 29.3; H, 3.4; N, 20.5%); $\lambda_{max}$(EtOH)/nm 300 (log ε 4.21), 327 (3.74) and 360 (3.72); $\nu_{max}(CCl_4)/cm^{-1}$ 1160 s; $\delta_H$(250 MHz; $CDCl_3$) 1.34 (3 H, d,

Me), 2.15 (1 H, m, CH), 2.40 (2 H, m, $CH_2$) and 7.13 (1 H, s); *m/z* (110 °C) 205 ($M^+$, 100%) and 159 ($M^+$ − NS, 20).

6-*Acetamido*-1,3λ$^4$δ$^2$,5,2,4-*trithiadiazepine* **13**.—6-Aminotrithiadiazepine **7** (31 mg, 0.19 mmol) in dichloromethane (25 ml) was treated with an excess of acetic anhydride (0.05 ml, 0.56 mmol) and refluxed for 18 h. The reaction mixture was then concentrated under reduced pressure and chromatrographed on silica. Elution with ethyl acetate gave the *title compound* (35 mg, 85%) as a colourless solid, m.p. 138–139 °C (from acetone) (Found: C, 23.4; H, 2.25; N, 20.1. $C_4H_5N_3OS_3$ requires C, 23.2; H, 2.4; N, 20.3%); $\lambda_{max}$(EtOH)/nm 234 (log ε 3.89) and 330 (3.65); $\nu_{max}$($CHCl_3$)/$cm^{-1}$ 3372w, 1694vs and 1159s $cm^{-1}$; $\delta_H$(250 MHz; [$^2H_6$]-DMSO) 2.05 (3 H, s, Me), 8.30 (1 H, s) and 10.35 (1 H, s); $\delta_C$(62.9 MHz; [$^2H_6$]-DMSO) 22.24 (Me), 130.6, 137.74 and 170.2 (CO); *m/z* (160 °C) 207 ($M^+$, 87%), 161 ($M^+$ − NS, 50), 119 (100) and 43 ($CH_3CO$, 90).

6-*Benzylideneaminotrithiadiazepine* **14**.—6-Aminotrithiadiazepine **7** (20 mg, 0.12 mmol) in acetonitrile (8 ml) was treated with benzaldehyde (30 mg, 0.28 mmol) and the mixture stirred at room temperature for 48 h. After this the solvent was removed under reduced pressure and the residue chromatographed on silica. Light petroleum–dichloromethane (50:50) eluted the *title compound* (22 mg, 72%) as a yellow solid, m.p. 120–121 °C (from light petroleum–dichloromethane) (Found: C, 42.9; H, 2.6; N, 16.6. $C_9H_7N_3S_3$ requires C, 42.7; H, 2.8; N, 16.6%); $\lambda_{max}$(EtOH)/nm 312 (log ε 4.01) and 364 (3.91); $\nu_{max}$($CCl_4$)/$cm^{-1}$ 1614 s, 1577 s and 1158 vs; $\delta_H$(250 MHz; $CDCl_3$) 7.50 (3 H, m), 7.90 (3 H, m) and 8.51 (1 H, s); *m/z* (150 °C) 253 ($M^+$, 100%) and 207 ($M^+$ − NS, 67).

6-*Aminotrithiadiazepine Hydrochloride* **12**.—6-Aminotrithiadiazepine **7** (100 mg, 0.61 mmol) in dry ether (20 ml) was treated with dry hydrogen chloride gas for 15 s. The product was then filtered off, washed with dichloromethane and dried to give the *title compound* (116 mg, 94%) as a pale yellow solid, m.p. 118–120 °C (decomp.) (Found: C,12.3; H, 2.4; N, 20.5. $C_2H_4ClN_3S_3$ requires C, 11.9; H, 2.0; N, 20.8%); $\lambda_{max}$(EtOH)/nm 325; $\nu_{max}$(KBr disc)/$cm^{-1}$ 1161; *m/z* (150 °C) 165 ($M^+$ − HCl, 100%) and 119 ($M^+$ − HCl, − NS, 20).

*Diazotisation of* 6-*Aminotrithiadiazepine*.—6-Aminotrithiadiazepine **7** (100 mg, 0.61 mmol) in THF (10 ml) at 0 °C was treated with concentrated hydrochloric acid (1 ml) followed by an excess of pentyl nitrite (1 ml). The mixture was then allowed to warm to room temperature when it was stirred for 15 h. After this the solvent was removed under reduced pressure and the residue chromatographed on silica. Light petroleum eluted 6-chlorotrithiadiazepine **15** (17 mg, 15%) as a yellow oil; $\lambda_{max}$(EtOH)/nm 338 (log ε 3.65); $\nu_{max}$($CCl_4$)/$cm^{-1}$ 1165vs; $\delta_H$(250 MHz; $CDCl_3$) 7.86 (1 H, S); *m/z* (100 °C) 184 ($M^+$, 81%), 149 ($M^+$ − Cl, 1) and 138 ($M^+$ − NS, 53).

### *Deuteriation Experiments*

The hydrogen:deuterium ratio in the deuteriated compounds was determined by mass spectrometry isotope abundance calculations. These were performed on an average mass spectrum calculated from 10 scans to give a more accurate result.

6-*Bromotrithiadiazepine with Morpholine and* $D_2O$.—6-Bromotrithiadiazepine (30 mg, 0.13 mmol) in THF (10 ml) with deuterium oxide (120 mg, 6 mmol) was treated with morpholine (57 mg, 0.66 mmol) at room temperature for 5 h. Solvent was then removed from the mixture under reduced pressure without heating and the products were isolated by chromatography on silica. Light petroleum eluted 6-bromotrithiadiazepine (5 mg, 16%) which was shown by mass spectrometry to be 80% deuteriated. Dichloromethane eluted 6-morpholinotrithiadiazepine **16** (31 mg, 75%) which was shown by mass spectrometry to be 90% deuteriated.

6-*Bromo*-7-*deuteriotrithiadiazepine*.—6-Acetoxymercurio-7-bromotrithiadiazepine[11] (100 mg, 0.21 mmol) in THF (20 ml) was treated with an excess of 37 wt % $D_2O$/DCl (1.5 ml) and the mixture stirred at room temperature for 1 h. The solvent was then removed under reduced pressure form the mixture and the product chromatographed on silica. Light petroleum eluted the *title compound* (43 mg, 89%) which was shown by mass spectrometry to be 98% deuteriated.

6-*Bromo*-7-*deuteriotrithiadiazepine with Morpholine*.—6-Bromo-7-deuteriotrithiadiazepine (30 mg, 0.13 mmol) in THF (10 ml) was treated with morpholine (120 mg, 6 mmol) at room temperature for 7 h. The solvent was then removed under reduced pressure from the mixture and the residue chromatographed on silica. Light petroleum eluted 6-bromotrithiadiazepine (3 mg, 10%) which was shown by mass spectrometry to contain < 10% 6-bromo-7-deuteriotrithiadiazepine. Dichloromethane eluted 6-morpholinotrithiadiazepine **10** (21 mg, 69%) which was shown by mass spectrometry to contain < 10% of 6-morpholino-7-deuteriotrithiadiazepine.

### *Trithiadiazepyne Cycloadducts*

(i) *Using Hünig's Base*.—6,9-*Dihydro*-1,3λ$^4$δ$^2$,5,2,4-*benzotrithiadiazepine* 6,9-*endoxide* **18**. 6-Bromotrithiadiazepine (500 mg, 2.2 mmol) and furan (3.0 g, 44 mmol) in methanol (30 ml) were treated with Hünig's base (563 mg, 4.4 mmol) at room temperature. After 20 min the reaction was concentrated and the residue chromatographed on silica. Elution with light petroleum–dichloromethane (50:50) gave the *title compound* (255 mg, 54%) as a yellow solid, m.p. 56–57 °C (from light petroleum–dichloromethane, 75:25) (Found: C, 33.5; H, 1.9; N, 12.9. $C_6H_4N_2OS_3$ requires C, 33.5; H, 1.85; N, 13.0%); $\lambda_{max}$(EtOH)/nm 250 (log ε 3.90) 324 (3.67) and 373 (3.70); $\nu_{max}$($CCl_4$)/$cm^{-1}$ 1151 vs; $\delta_H$(250 MHz; $CDCl_3$) 5.9 (2 H, t, *J*/Hz 1.4 and 1.2) and 7.2 (2 H, t, *J*/Hz 1.4 and 1.2); $\delta_C$(62.9 MHz; $CDCl_3$) 86.7, 142.4 and 148.4; *m/z* (170 °C) 216 ($M^+$, 100%) and 170 ($M^+$ − NS, 26).

6,9-*Dimethyl*-1,3λ$^4$δ$^2$,5,2,4-*benzotrithiadiazepine* 6,9-*endoxide* **19**. 6-Bromotrithiadiazepine (500 mg, 2.2 mmol) and 2,5-dimethylfuran (2.1g, 21.8 mmol) in methanol (30 ml) were treated with Hünig's base (563 mg, 4.4 mmol) at room temperature. After 20 min the reaction mixture was concentrated and the residue chromatographed on silica. Light petroleum–dichloromethane (50:50) eluted the *title compound* (320 mg, 60%) as a yellow oil (Found: C, 39.5; H, 3.4; N, 11.5. $C_8H_8N_2OS_3$ requires C, 39.4; H, 3.3; N, 11.5%); $\lambda_{max}$EtOH)/nm 250 (log ε 4.0), 324 (3.68) and 375 (3.79); $\nu_{max}$($CCl_4$)/$cm^{-1}$ 1150; $\delta_H$(250 MHz; $CDCl_3$) 1.9 (6 H, s, 2 × Me) and 7.1 (2 H, s); $\delta_C$(62.9 MHz; $CDCl_3$) 16.3 (2 × Me), 93.6 (*C*-Me), 146.8 and 152.6; *m/z* (150 °C) 244 ($M^+$, 72%), 198 ($M^+$ − NS, 10) and 201 ($M^+$ − $CH_3CO$, 9).

6,11-*Diphenyl*-1,3λ$^4$δ$^2$,5,2,4-*naphthalenotrithiadiazepine* 6,11-*endoxide* **22**. 6-Bromotrithiadiazepine (50 mg, 0.22 mmol) and 1,3-diphenylisobenzofuran (118 mg, 0.44 mmol) in methanol (10 ml) were treated with Hünig's base (95 mg, 0.07 mmol). The mixture was stirred at room temperature for 10 min after which solvent was removed and the residue chromatographed on silica. Light petroleum–dichloromethane (75:25) eluted the *title compound* (76 mg, 83%) as a yellow solid, m.p. 214–216 °C (from light petroleum–dichloromethane 95:5) (Found: C, 63.1; H, 3.5; N, 6.8 $C_{22}H_{14}N_2OS_3$ requires C, 63.2; H, 3.4; N, 6.7%);

$\lambda_{max}$(EtOH)/nm 250 (log ε 4.16), 329 (3.69) and 367 (3.81); $\nu_{max}(CCl_4)/cm^{-1}$ 1154; $\delta_H$(250 MHz; $CDCl_3$) 7.1 (2 H, m, Ph), 7.55 (8 H, m, Ph) and 8.1 (4 H, m, Ph); $\delta_C$(62.9 MHz; $CDCl_3$) 94.7, 120.3, 126.0, 127.1, 128.8, 129.4, 133.6, 150.0 and 152.4; *m/z* (190 °C) 418 ($M^+$, 5%), 372 ($M^+$ − NS, 12), 340 ($M^+$ − $NS_2$, 45) and 270 ($M^+$ − 148, 33).

6,9-*Dihydro*-6,9-*methano*-1,3$\lambda^4\delta^2$,5,2,4-*benzotrithiadiazepine* **23**. 6-Bromotrithiadiazepine (500 mg, 2.2 mmol) and cyclopentadiene (3.0 g, 45 mmol) in methanol (40 ml) were treated with Hünig's base (845 mg, 6.6 mmol) at room temperature. The mixture was stirred for 1 h after which the solvent was removed and the residue chromatographed on silica. Light petroleum–dichloromethane (75:25) eluted the *title compound* (438 mg, 94%) as a yellow oil (Found: C, 39.3; H, 2.9; N, 12.9. $C_7H_6N_2S_3$ requires C, 39.3; H, 2.8; N, 13.1%); $\lambda_{max}$(EtOH)/nm 245 (log ε 3.74), 325 (3.49) and 372 (3.58); $\nu_{max}(CCl_4)/cm^{-1}$ 1142; $\delta_H$(250 MHz; $CDCl_3$) 2.28 (1 H, dt, *J*/Hz 7.0 and 3.6), 2.60 (1 H, dt, *J*/Hz and 3.3), 4.14 (2 H, m) and 6.90 (2 H, t, *J*/Hz 2.5 and 2); $\delta_C$(62.9 MHz; $CDCl_3$) 55.6, 70.2, 142.6 and 149.0; *m/z* (160 °C) 214 ($M^+$, 100%) and 168 ($M^+$ − NS, 40).

6,9-*Dihydro*-7,8-*dimethylbenzotrithiadiazepine* **20**. 6-Bromotrithiadiazepine (60 mg, 0.26 mmol) in a solution of methanol (5 ml) and 2,3-dimethylbutadiene (2 ml) was treated with Hünig's base (72 mg, 0.06 mmol) at room temperature. The mixture was stirred for 10 h after which the solvent was removed and the residue chromatographed on silica. Light petroleum eluted the *title compound* (40 mg, 66%) as a colourless solid, m.p. 140–141 °C (from $CHCl_3$) (Found: C, 41.7; H, 4.2; N, 12.1. $C_8H_{10}N_2S_3$ requires C, 41.7; H, 4.4; N, 12.2%); $\lambda_{max}$(EtOH)/nm 233 (log ε 3.91) and 343 (3.86); $\nu_{max}(CCl_4)/cm^{-1}$ 1167; $\delta_H$(250 MHz; $CDCl_3$) 1.8 (6 H, s, 2 × Me) and 3.33 (4 H, s, $CH_2$); *m/z* (170 °C) 230 ($M^+$, 100%) and 184 ($M^+$ − NS, 46).

6,9-*Dihydro*-6,9-*isopropylidenemethano*-1,3$\lambda^4\delta^2$,5,2,4-*benzotrithiadiazepine* **21**. 6-Bromotrithiadiazepine (40 mg, 0.17 mmol) and 6,6-dimethylfulvene (100 mg, 0.9 mmol) in methanol (10 ml) were treated with Hünig's base (72 mg, 0.6 mmol). The mixture was stirred at room temperature for 1 h after which the solvent was removed and the residue chromatographed on silica. Light petroleum–dichloromethane (80:20) eluted the *title compound* (31 mg, 70%) as a pale yellow solid, m.p. 95–96 °C (from methanol) (Found: C, 47.2; H, 3.9; N, 10.9. $C_{10}H_{10}N_2S_3$ requires C, 47.2; H, 3.9; N, 11.0%); $\lambda_{max}$(EtOH)/nm 244 (log ε 3.96), 325 (3.62) and 378 (3.79); $\nu_{max}(CCl_4)/cm^{-1}$ 1147; $\delta_H$(250 MHz; $CDCl_3$) 1.55 (6 H, s), 4.58 (2 H, t, *J* 2.5 and 2 Hz) and 7.19 (2 H, t, *J*/Hz 2.5 and 2.0); $\delta_C$(62.9 MHz; $CDCl_3$) 18.4 (2 × Me), 54.8, 100.7, 142.8, 148.8 and 158.4; *m/z* (120 °C) 254 ($M^+$, 100%) and 208 ($M^+$ − NS, 42).

6,7-*Di*(*trithiadiazepinyl*)*trithiadiazepine* **24**. 6-Bromotrithiadiazepine (200 mg, 0.87 mmol) in methanol (15 ml) was treated with Hünig's base (225 mg, 1.7 mmol) at room temperature. The mixture was stirred for 10 min after which the solvent was removed under reduced pressure and the residue chromatographed on silica. Light petroleum–dichloromethane (75:25) eluted the title compound (14 mg, 11%) as a crystalline solid, m.p. 196–197 °C. The compound is best purified by washing with light petroleum–dichloromethane (50:50) (Found: 445.7822 $C_6H_2N_6S_9$ requires 445.7919); $\lambda_{max}$(EtOH)/nm 332; $\nu_{max}(CHCl_3)/cm^{-1}$ 1158; *m/z* (180 °C) 446 ($M^+$, 37%), 400 ($M^+$ − NS, 9%) and 354 ($M^+$ − $N_2S_2$, 19%).

(ii) *Using Sodium Methoxide*.—6,9-*Dihydro*-1,3$\lambda^4\delta^2$,5,2,4-*benzotrithiadiazepine* 6,9-*endoxide* **18**. A vigorously stirred solution of 6-bromotrithiadiazepine (520 mg, 2.27 mmol) and furan (3.0 g, 44 mmol) in methanol (100 ml) was slowly treated with a solution of sodium methoxide (307 mg, 5.7 mmol) in methanol added dropwise over 30 min. The solvent was then removed under reduced pressure and the residue chromatographed on silica. Light petroleum–dichloromethane (75:25) eluted the title compound (360 mg, 73%) identical with that previously described.

6,9-*Dimethyl*-1,3$\lambda^4\delta^2$,5,2,4-*benzotrithiadiazepine* 6,9-*endoxide* **19**. A vigorously stirred solution of 6-bromotrithiadiazepine (500 mg, 2.18 mmol) and 2,5-dimethylfuran (2.1 g, 22 mmol) in methanol (100 ml) was slowly treated with a solution of sodium methoxide (295 mg, 5.46 mmol) in methanol (50 ml) added dropwise over 30 min. The solvent was then removed under reduced pressure and the residue chromatographed on silica. Light petroleum–dichloromethane (75:25) eluted the title compound (401 mg, 75%) identical with that previously described.

6,9-*Dihydro*-6-*methyl*-1,3$\lambda^4\delta^2$,5,2,4-*benzotrithiadiazepine* 6,9-*endoxide*. A vigorously stirred solution of 6-bromotrithiadiazepine (330 mg, 1.44 mmol) and 2-methylfuran (2.4 g, 29 mmol) in methanol (50 ml) was slowly treated with a solution of sodium methoxide (194 mg, 3.6 mmol) in methanol (50 ml) added dropwise over 30 min. The solvent was then removed under reduced pressure and the residue chromatographed on silica. Light petroleum–dichloromethane (50:50) eluted the *title compound* (262 mg, 79%) as a yellow solid, m.p. 41–42 °C (from acetone) (Found: 36.4; H, 2.4; N, 12.2. $C_7H_6N_2OS_3$ requires C, 36.5; H, 2.6; N, 12.2%); $\lambda_{max}$(EtOH)/nm 252 (log ε 4.00), 326 (3.70) and 370 (3.75); $\nu_{max}(CCl_4)/cm^{-1}$ 1152vs, 1133vs; $\delta_H$(250 MHz; $CDCl_3$) 2.00 (3 H, s, Me), 5.73 (1 H, d, *J*/Hz 1.7), 7.02 (1 H, d, *J*/Hz 5.1) and 7.21 (1 H, dd, *J*/Hz: 5.1 and 1.7); $\delta_C$(62.9 MHz; $CDCl_3$) 16.2 (Me), 84.4, 96.1, 143.6, 145.6, 149.6 and 151.0; *m/z* (140 °C) 230 ($M^+$, 100%) and 184 ($M^+$ − NS, 18).

6,11-*Diphenyl*-1,3$\lambda^4\delta^2$,5,2,4-*naphthalenotrithiadiazepine* 6,11-*endoxide* **22**. A vigorously stirred solution of 6-bromotrithiadiazepine (100 mg, 0.44 mmol) and 1,3-diphenylisobenzofuran (118 mg, 0.44 mmol) in methanol (50 ml) was slowly treated with a solution of sodium methoxide (59 mg, 1.1 mmol) in methanol (50 ml) added dropwise over 30 min. The solvent was removed under reduced pressure and the residue chromatographed on silica. Light petroleum–dichloromethane eluted the title compound (168 mg, 92%) identical with that previously described.

6,9-*Dihydro*-6,9-*dimethylaminomethylenemethano*-1,3$\lambda^4\delta^2$,5,2,4-*benzotrithiadiazepine*.—A vigorously stirred solution of 6-bromotrithiadiazepine (200 mg, 0.87 mmol) and 6-dimethylaminofulvene (270 mg, 2.23 mmol) in methanol (50 ml) was treated with a solution of sodium methoxide (118 mg, 2.2 mmol) in methanol (50 ml) dropwise over 30 min. The solvent was then removed under reduced pressure and the residue chromatographed on silica. Light petroleum–dichloromethane (50:50) eluted the *title compound* (58 mg, 25%) as a yellow solid, m.p. 156–157 °C (from light petroleum–dichloromethane) (Found: C, 44.6; H, 4.0; N, 15.6. $C_{10}H_{11}N_3S_3$ requires C, 44.6; H, 4.1; N, 15.6%); $\lambda_{max}$(EtOH)/nm 264 (log ε 3.0) and 338 (3.62); $\nu_{max}(CCl_4)/cm^{-1}$ 1620vs, 1286s and 1153w; $\delta_H$(250 MHz; $CDCl_3$) 3.30 (6 H, s, 2 × Me), 6.48 (1 H, dd, *J*/Hz 4.5 and 2.5), 6.58 (1 H, dd, *J*/Hz 2.8 and 2), 6.76 (1 H, dd, *J*/Hz 5.0 and 2.0), 7.31 (1 H, s) and 7.52 (1 H, s); *m/z* (160 °C) 269 ($M^+$, 100%) and 223 ($M^+$ − NS, 17).

6-*Iodotrithiadiazepine*.—(i) 6-Bromotrithiadiazepine (170 mg, 0.74 mmol) in methanol (15 ml) was treated with tetrabutylammonium iodide (630 mg, 2.3 mmol) at room temperature. After 48 h the solvent was removed under reduced pressure and the residue chromatographed on silica by dry flash chromatography. Light petroleum–dichloromethane (75:25) eluted the *title compound* (145 mg, 71%) as pale yellow plates, m.p. 92–94 °C (from light petroleum) (Found: C, 8.8; H, 0.35; N, 9.95. $C_2HIN_2S_3$ requires C, 8.7; H, 0.4; N, 10.1%); $\lambda_{max}$(EtOH)/nm 224 (log ε 3.74), 244 (3.57), 325 (3.22), and 345 (3.24); $\nu_{max}(CHCl_3)/cm^{-1}$ 2920, 2850, 1150, 993, 905, 855 and 640; $\delta_H$(90 MHz; $CDCl_3$) 7.66 (s); *m/z* 276 ($M^+$, 100%), 230 (25), 184 (11), 127 (17), 124 (25), 105 (20), 103 (26), 78 (54) and 46 (59).

(ii) 6-Bromotrithiadiazepine (100 mg, 0.44 mmol) and tetrabutylammonium iodide (320 mg, 1.97 mmol) in methanol (15 ml) were treated with Hünig's base (56 mg, 0.44 mmol) at room temperature. The mixture was stirred for 15 min after which the solvent was removed under reduced pressure and the product isolated by dry flash chromatography on silica. Light petroleum–dichloromethane (75:25) eluted the title compound (51%) identical with that described above.

### *Competition Experiments*

*Trithiadiazepyne from Different Precursors.*—(i) 6-Bromotrithiadiazepine (50 mg, 0.22 mmol), furan (445 mg, 6.6 mmol) and 2,5-dimethylfuran (210 mg, 2.2 mmol) in methanol (10 ml) were treated with Hünig's base (56 mg, 0.44 mmol). The reaction mixture was stirred at room temperature for 15 min after which it was concentrated and the residue chromatographed on silica. Light petroleum–dichloromethane (75:25) eluted a mixture of 6,9-dihydro-1,3$\lambda^4\delta^2$,5,2,4-benzotrithiadiazepine 6,9-endoxide **18** and 6,9-dimethyl-1,3$\lambda^4\delta^2$,5,2,4-benzotrithiadiazepine 6,9-endoxide **19**. $^1$H NMR on the total chromatographic fraction containing the adducts showed a product ratio of 1.00:1.27 respectively.

(ii) 6-Chlorotrithiadiazepine (40 mg, 0.22 mmol), furan (445 mg, 6.6 mmol), and 2,5-dimethylfuran (210 mg, 2.2 mmol) in methanol (10 ml) were treated with Hünig's base (56 mg, 0.44 mmol). The reaction mixture was stirred at room temperature for 3 h after which it was concentrated and the residue chromatographed on silica. Light petroleum–dichloromethane (75:25) eluted the product mixture as before. $^1$H NMR on the total chromatographic fraction containing the adducts showed a product ratio of 1.00:1.29 respectively.

(iii) 6-Iodotrithiadiazepine (60 mg, 0.22 mmol) furan (445 mg, 6.6 mmol) and 2,5-dimethylfuran (210 mg, 2.2 mmol) in methanol (10 ml) were treated with Hünig's base (56 mg, 0.44 mmol). The reaction mixture was stirred at room temperature for 3 h after which it was concentrated and the residue chromatographed on silica. Light petroleum–dichloromethane (75:25) eluted the product mixture as before. $^1$H NMR on the total chromatographic fraction showed a product ratio of 1.00:1.29 respectively.

*6-Bromotrithiadiazepine and 1,3-Diphenylisobenzofuran with Morpholine.*—6-Bromotrithiadiazepine (50 mg, 0.22 mmol) and 1,3-diphenylisobenzofuran (118 mg, 0.44 mmol) in THF (10 ml) were treated with morpholine (95 mg, 1.1 mmol) at room temperature. The mixture was stirred for 10 h after which the solvent was removed under reduced pressure and the residue chromatographed on silica. Light petroleum–dichloromethane (90:10) eluted 1,3-diphenylisobenzofuran followed by 6,11-diphenylnaphthalenotrithiadiazepine 6,11-endoxide **22** (2.8 mg, 3%) identical with that previously described. Light petroleum–dichloromethane (50:50) eluted 6-morpholinotrithiadiazepine **10** (38 mg, 74%) identical with that previously described.

*6-Bromotrithiadiazepine with 1,3-Diphenylisobenzofuran and Diisopropylamine.*—6-Bromotrithiadiazepine (50 mg, 0.22 mmol) and 1,3-diphenylisobenzofuran (118 mg, 0.44 mmol) in THF (10 ml) were treated with diisopropylamine (110 mg, 1.10 mmol) at room temperature. After 5 h the solvent was removed under reduced pressure and the residue chromatographed on silica. Light petroleum eluted 6-diisopropylaminotrithiadiazepine **6** (30 mg, 54%). Dichloromethane–light petroleum (10:90) eluted 1,3-diphenylisobenzofuran followed by 6,11-diphenylnaphthalenotrithiadiazepine 6,11-endoxide **22** (10 mg, 11%) identical with that described previously.

*6-Bromotrithiadiazepine with 1,3-Diphenylisobenzofuran and 2,2,6,6-Tetramethylpiperidine.*—6-Bromotrithiadiazepine (50 mg, 0.22 mmol) and 1,3-diphenylisobenzofuran (118 mg, 0.44 mmol) in THF (10 ml) were treated with tetramethylpiperidine (154 mg, 1.10 mmol) at room temperature. The mixture was stirred for 6 h after which the solvent was removd under reduced pressure and the residue chromatographed on silica. Light petroleum–dichloromethane (90:10) eluted 1,3-diphenylisobenzofuran followed by 6,11-diphenylnaphthalenotrithiadiazepine 6,11-endoxide **22** (70 mg, 76%).

*6-Bromotrithiadiazepine with Hünig's Base.*—6-Bromotrithiadiazepine (20 mg, 0.09 mmol) in methanol–THF (45:55; 4 ml) was treated with Hünig's base (56 mg, 0.43 mmol) at room temperature. TLC monitoring of the reaction indicated that it took 9 h for the starting material to be consumed.

*6-Bromotrithiadiazepine and 1,3-Diphenylisobenzofuran with Hünig's Base.*—6-Bromotrithiadiazepine (20 mg, 0.09 mmol) and 1,3-diphenylisobenzofuran (24 mg, 0.09 mmol) in methanol–THF (45:55; 4 ml) was treated with Hünig's base (56 mg, 0.43 mmol). TLC monitoring of the reaction indicated it took 2 h for the starting material to be consumed.

*6-Bromotrithiadiazepine and 2,5-Dimethylfuran with Hünig's Base.*—6-Bromotrithiadiazepine (20 mg, 0.09 mmol) and 2,5-dimethylfuran (34 mg, 0.4 mmol) in methanol–THF (45:55; 4 ml) was treated with Hünig's base (56 mg, 0.43 mmol) at room temperature. TLC monitoring of the reaction indicated it took 3.5 h for the starting material to be consumed.

*6-Bromotrithiadiazepine and Hünig's Base Hydrobromide with Hünig's Base.*—Hünig's base hydrobromide was prepared by treating the base in ether with hydrogen bromide in acetic acid. The product was filtered off and dried. 6-Bromotrithiadiazepine (20 mg, 0.09 mmol) and Hünig's base hydrobromide (183 mg, 0.9 mmol) in a methanol–THF (45:55) mixture (4 ml) was treated with Hünig's base (56 mg, 0.43 mmol) at room temperature. TLC monitoring of the reaction indicated that it took 55 h for the starting material to be consumed.

*6-Bromotrithiadiazepine, 1,3-Diphenylisobenzofuran and Hünig's Base Hydrobromide with Hünig's Base.*—6-Bromotrithiadiazepine (20 mg, 0.09 mmol), 1,3-diphenylisobenzofuran (24 mg, 0.09 mmol) and Hünig's base hydrobromide (183 mg, 0.9 mmol) in methanol–THF (45:55; 4 ml) were treated with Hünig's base (56 mg, 0.43 mmol) at room temperature. TLC monitoring of the reaction indicated that it took 2.5 h for the starting material to be consumed.

## Acknowledgements

We thank the SERC for a studentship (M. J. P.), Dr. J. L. Morris for some early experiments, and Dr. H. S. Rzepa for the MNDO calculations.

## References

1 Part 13, R. M. Bannister and C. W. Rees, *J. Chem. Soc., Perkin Trans. 1*, 1990, 509.
2 P. J. Dunn and C. W. Rees, *J. Chem. Soc., Perkin Trans. 1*, 1987, 1579, 1585.
3 J. L. Morris and C. W. Rees, *J. Chem. Soc., Perkin Trans. 1*, 1987, 211.
4 J. L. Morris and C. W. Rees, *J. Chem. Soc., Perkin Trans. 1*, 1987, 217.
5 P. J. Dunn, J. L. Morris and C. W. Rees, *J. Chem. Soc., Perkin Trans. 1*, 1988, 1745.
6 P. J. Dunn and C. W. Rees, *J. Chem. Soc., Perkin Trans. 1*, 1989, 1405.
7 J. L. Morris and C. W. Rees, *Chem. Soc. Rev.*, 1986, **15**, 1.
8 Dr. H. S. Rzepa, unpublished MNDO calculations.
9 A. Krebs and J. Wilke, *Top. Curr. Chem.*, 1983, **109**, 189.

10 M. J. Plater, C. W. Rees, A. M. Z. Slawin and D. J. Williams, *J. Chem. Soc., Chem. Commun.*, 1990, 1315.
11 C. W. Rees and J. R. J. Surtees, unpublished results.
12 B. H. Klanderman and T. R. Criswell, *J. Am. Chem. Soc.*, 1969, **91**, 510.
13 W. J. Spillane, P. Kavanagh, F. Young, H. J-M. Dou and J. Metzger, *J. Chem. Soc., Perkin Trans. 1*, 1981, 1763.
14 R. A. Olofson, J. M. Landesberg, K. N. Houk and J. S. Michelman, *J. Am. Chem. Soc.*, 1966, **88**, 4263, 4265.

*Paper* 0/03196H
*Received* 16*th July* 1990
*Accepted* 31*st July* 1990