ABSTRACT

There is only one report in the literature of a structure of the trithiapentalene type containing the =N—S unit. We have thionated 3,4-dimethyl-1-oxa-6,6a λ^4-diselena-2-azapentalene with phosphorus pentasulphide and obtained two products, 3,4-dimethyl-1-thia-6,6a λ^4-diselena-2-azapentalene and 3,4-dimethyl-1,6-dithia-6a λ^4-selena-2-azapentane, both new systems which contain this moiety. A third product from the same reaction was 3,4-dimethyl-1-oxa-6-thia-6a λ^4-selena-2-azapentalene, the first trithiapentalene analogue containing four different heteroatoms. An attempt to introduce the =N—S unit into 4,5-dihydro-3H-benzo-[cd]-1-oxa-6,6a λ^4-dithia-2-azapentalene by treatment with phosphorus pentasulphide was unsuccessful.

We have demonstrated that the very large increase in acidity of isothiazole-5-carboxaldoxime on methylation at N-2, which had been reported in the literature, is due to the formation of a stabilised bicyclic three-centre bonded structure on deprotonation of the resulting salt in solution. This investigation thus led to the isolation of 6-methyl-1-oxa-6a λ^4-thia-2,6-diazapentalene, the first member of a new heterocyclic system. An attempt to introduce the =N—S unit into this product by thionation with phosphorus pentasulphide was precluded by the low yield in which this compound was obtained. Several other related compounds were also studied.

It has been suggested that the products from reactions of 1,6,6a λ^4-trithiapentalenes with arenediazonium electrophiles arise from two distinct mechanisms, one involving attack at C-3(4) and the other involving attack at S-1(6). We have provided further verification of the latter mechanism by obtaining S-arylation products from the reaction of 5-methyl(ene)-1,2-dithiole-3-thiones with arenediazonium tetrafluoroborates. We have also trapped a dithiolium salt intermediate from this type of reaction as 3-p-nitrophenylthio-5-t-butyl-1,2-dithiolium tetrafluoroborate.

To Mr. Loukes

STUDIES OF 2-AZA ANALOGUES OF 1,6,6aλ^4-TRITHIA-PENTALENES : INTRODUCTION OF THE =N–S UNIT INTO FOUR-ELECTRON THREE-CENTRE BONDED STRUCTURES

and

REACTIONS OF 1,6,6aλ^4-TRITHIAPENTALENES WITH ARENEDIAZONIUM TETRAFLUOROBORATES

a Thesis

presented by

ALEXANDER GIBSON BRIGGS

to

The University of St. Andrews

in application for the degree of M.Sc.

DECLARATION

I hereby declare that the following thesis is based on the results of experiments carried out by me, that it is of my own composition, and that it has not been submitted previously in application for a higher degree.

August 1977 Alexander G. Briggs

CERTIFICATE

I hereby certify that Alexander G. Briggs has spent six terms conducting research under my supervision, has fulfilled the conditions of the Resolution of the University Court 1974 No. 2, and is qualified to submit the accompanying thesis in application for the degree of Master of Science.

August 1977

Professor D.H. Reid
Director of Research

UNIVERSITY CAREER

I entered the Chemistry program at Mount Allison University (New Brunswick, Canada) in September 1971. During my four years there two summers were spent conducting research under the supervision of Professor L.R.C. Barclay, and in May 1975 I received the degree of B.Sc. with First Class Honours in Chemistry, with Distinction.

In October 1975 I was awarded a University of St. Andrews Research Scholarship and from then until May 1977, under the supervision of Professor D.H. Reid, I carried out the work which is embodied in this thesis.

ACKNOWLEDGEMENTS

Special thanks are due to Professor D.H. Reid for his continued help and guidance throughout the course of this work, and to the University of St. Andrews for a Research Scholarship without which my stay in St. Andrews would not likely have been possible.

I wish also to express my gratitude to Professor Lord Tedder and Professor P.A.H. Wyatt for permission to use the excellent research facilities of the Department of Chemistry.

In addition, I wish to thank the technical staff of the Chemistry Department for the high quality services which they provide, and I am very grateful to Mrs. W. Pogorzelec for the typing of this thesis.

EXPLANATORY NOTE

This thesis is divided into two topically independent parts, and each part is divided into three sections.

The first section of each part consists of a review of the background literature relevant to the work embodied in that part. The discussions of structure, bonding and, to a lesser extent, syntheses, which appear in Part I are, however, also relevant to Part II.

The second section of each part is a discussion of the results obtained in the course of the investigation.

The third section of each part contains the experimental details of the reactions studied in that part.

When reference is made to the chemical literature this is indicated by a number in superscript, a key to which can be found at the end of Part II. The structural formulae which have been reproduced for illustrative purposes have been assigned Arabic numerals which correspond to the numbers which have been assigned to the relevant compounds in the text. The structure keys to Parts I and II are independent, and within each part the structure key for the review of the background literature is distinct from the one structure key used throughout the discussion of results and the experimental section.

CONTENTS

PART I

STUDIES OF 2-AZA ANALOGUES OF 1, 6, 6a λ^4-TRITHIA-PENTALENES: INTRODUCTION OF THE =N—S UNIT INTO FOUR-ELECTRON THREE-CENTRE BONDED STRUCTURES

Page

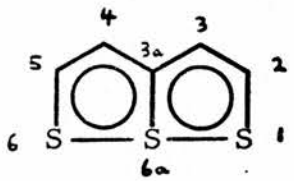
EXPERIMENTAL

PART II

REACTIONS OF 1, 6, 6a λ^4-TRITHIAPENTALENES WITH ARENEDIAZONIUM TETRAFLUOROBORATES

NOTE ON NOMENCLATURE

It is common in the literature to refer to the system formulated (I) as 6a-thiathiophthen, with numbering as shown.



I

The disadvantage of this nomenclature is that it cannot be extended to include the many possible oxygen, selenium, or nitrogen analogues of (I). A nomenclature based on pentalene which overcomes this problem has been proposed by Lozac'h[39]. It is widly used in the literature and is used in this thesis. Thus (I) becomes 1, 6, 6a λ^4-trithiapentalene. Chemical Abstracts indexes the system as [1, 2]-dithiolo-[1, 5-b][1, 2]dithiole-7-S^{IV}.

SUMMARY

There is only one report in the literature of a structure of the trithiapentalene type containing the =N—S unit. We have thionated 3,4-dimethyl-1-oxa-6,6a λ^4-diselena-2-azapentalene with phosphorus pentasulphide and obtained two products, 3,4-dimethyl-1-thia-6,6a λ^4-diselena-2-azapentalene and 3,4-dimethyl-1,6-dithia-6a λ^4-selena-2-azapentane, both new systems which contain this moiety. A third product from the same reaction was 3,4-dimethyl-1-oxa-6-thia-6a λ^4-selena-2-azapentalene, the first trithiapentalene analogue containing four different heteroatoms. An attempt to introduce the =N—S unit into 4,5-dihydro-3H-benzo-[cd]-1-oxa-6,6a λ^4-dithia-2-azapentalene by treatment with phosphorus pentasulphide was unsuccessful.

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PART I

STUDIES OF 2-AZA ANALOGUES OF 1,6,6aλ^4-TRITHIAPENTALENES: INTRODUCTION OF THE =N–S UNIT INTO FOUR-ELECTRON THREE-CENTRE BONDED STRUCTURES

DISCUSSION OF BACKGROUND LITERATURE

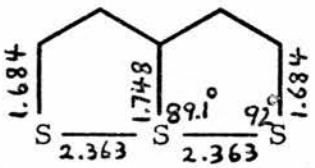
1. Studies of 2-Aza Analogues of 1, 6, 6a λ^4-Trithiapentalene

(a) Structure

It is now established that 1, 6, 6a λ^4-trithiapentalene (1)[1] and its many substituted derivatives [e.g. (2)[2], (3)[3], and (4)[4]] are bicyclic planar molecules having a more or less collinear arrangement of sulphur atoms[5-7]. The S—S distances in these compounds (see page 2) are significantly greater than the S—S bond length in a cis planar disulphide (2.10 Å)[8], but considerably shorter than twice the van der Waals' radius of sulphur (3.7 Å)[9]. The two S—S bonds in a given structure of the trithiapentalene type are not always equal in length, even for symmetrically substituted examples (3)[3]. Hordvik and Saethre[10] have reported a study of this variation of S—S bond lengths and conclude that these long bonds are sensitive to both intramolecular (substituent) and intermolecular effects.

It is also known that many analogues of 1, 6, 6a λ^4-trithiapentalenes in which one or more sulphur atoms are replaced by oxygen, selenium or nitrogen have structures which do not deviate greatly from the trithiapentalene model[5-7]. The S—S distances in the oxadithiapentalenes (5)[11] and (6)[12] (see page 2) are relatively close to the typical S—S bond lengths in disulphides (ca. 2.08 Å)[5], indicating a stronger S—S bond than in trithiapentalenes. The S—O distances in these compounds, while greater than the sum of the covalent radii of oxygen and sulphur (ca. 1.43 Å)[9], are still much

distances in Å



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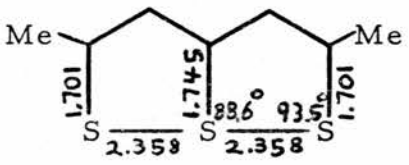

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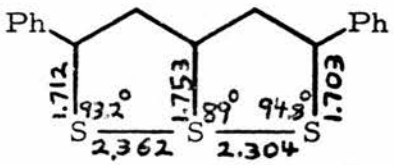

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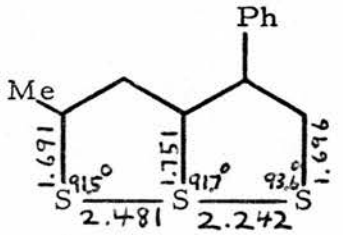

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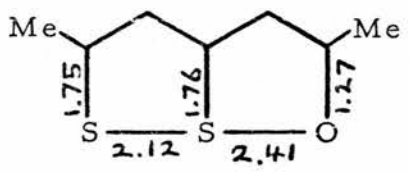

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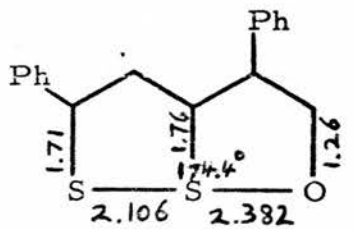

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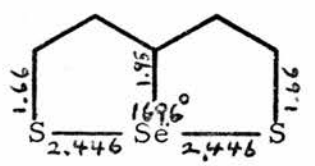

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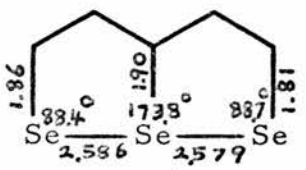

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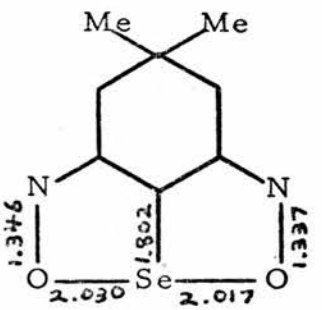

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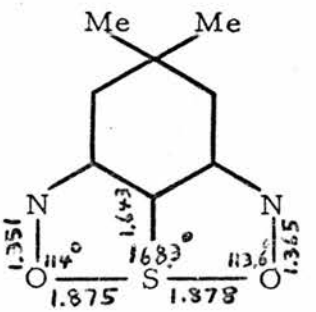

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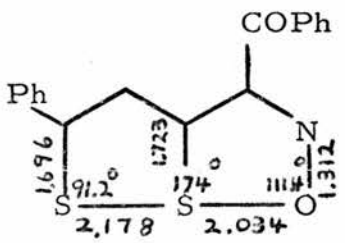

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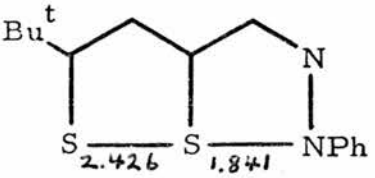


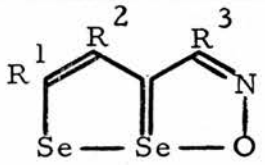
12

shorter than the sum of the van der Waals' radii of these two elements (ca. 3.25 Å)[9], indicating a significant bonding interaction.

The S—Se and Se—Se bond lengths in 1,6-dithia-6aλ^4-selenapentalene (7)[13] and 1,6,6aλ^4-triselenapentalene (8)[14] exceed by 10% the expected values for S—Se (2.22 Å)[9] and Se—Se (2.34 Å)[14] covalent bonds. These long bonds support a bicyclic formulation for these structures.

X-Ray structure determinations have been carried out on the dioxaselenadiazapentalene (9)[15] and on the dioxathiadiazapentalene (10)[16], and the O—Se and O—S bonds in these molecules are considerably shorter than the sum of the van der Waals' radii of oxygen and selenium and of oxygen and sulphur, respectively.

Furthermore, and of special interest to this work, Beer et al.[17] have prepared the oxadithia-azapentalene (11) and provided evidence (samples not intensely coloured like true nitroso compounds; i.r. carbonyl stretching band at 1640 cm^{-1}) for a significant interaction between the central sulphur atom and the oxygen of the "nitroso" group. An X-ray structure determination of this compound (11)[18,19] has shown the S—S distance to be significantly longer than that in normal disulphides, and the relatively short S—O distance (2.034 Å) is indicative of a stronger interaction than in oxadithiapentalenes [eg. (5) and (6)]. Reid and his co-workers[20] have provided ^1H nmr evidence in agreement with a bicyclic formulation for this compound, and have provisionally formulated some examples of the 1-oxa-6,6aλ^4-diselena-2-azapentalene system (13) as bicyclic.



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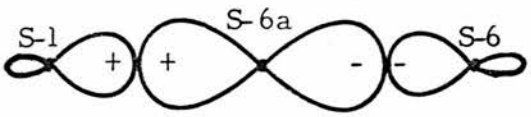
Hordvik et al.[21] have shown that the S—S bond length in the dithiadiazapentalene (12) is similar to that in trithiapentalenes, and the S—N distance (1.841 Å) is greater than the S—N covalent bond length (ca. 1.75 Å) but much less than the sum of the van der Waals' radii of sulphur and nitrogen (3.35 Å)[9]. These data support the formulation of 2-aza analogues of trithiapentalene as bicyclic structures.

(b) Bonding

From the preceding discussion follows the likelihood that the bonding in 2-aza analogues of 1,6,6aλ^4-trithiapentalenes may be formulated along the same lines as for trithiapentalenes themselves. The evolution of ideas[22-38] concerning the bonding in such molecules has included reasonably successful proposals[26-28,33] requiring valence shell expansion of the central heteroatom to allow d-orbital participation in classical σ bonding. It seems now, however, reasonable to accept[5,14,39-42] as a model four-electron three-centre bonding as postulated by Gleiter and Hoffman[32]. From three atomic (p) orbitals, one from each of the (approximately) collinear heteroatoms, are formed three molecular orbitals, one bonding, one non-bonding, and one anti-bonding. The electron density of the fully occupied bonding molecular orbital is delocalised



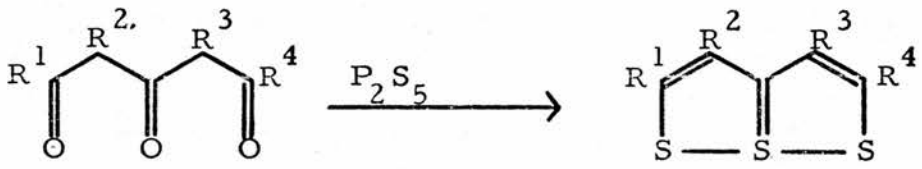
Four-electron Three-centre Bonding in Trithiapentalenes

over the three heteroatoms, while the non-bonding orbital, also fully occupied, has its charge mainly localised on the two lateral centres. The anti-bonding orbital is vacant. Gleiter and Hoffmann[32] consider that three-centre bonding of this type is stabilised by π bonding (which has been shown to exist)[33] between the three heteroatoms, although this effect is small since p-p π overlaps is still small at the equilibrium distance for the three-centre bond. The fact that, in this model, only two electrons bind the three centres together helps to account for the unusually long bonds observed (see section a). 1,6,6a λ^4-Trithiapentalenes and analogues, like naphthalene, are 10-π electron systems. The two lateral heteroatoms each provide two electrons to this π system, while the central heteroatom and all other atoms of the bicyclic nucleus each provide one.

(c) Synthetic Routes

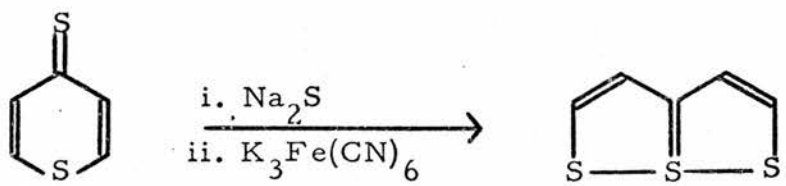
A substantial part of this thesis is concerned with the synthesis of 2-aza derivatives of 1,6,6a λ^4-triheterapentalenes. It is therefore useful to consider the established reactions which have led to such systems, and in order to do this it is convenient to construct the following system of classification.

The syntheses of 1, 6, 6aλ^4-trithiapentalene, its many derivatives and oxa, selena and aza analogues, offer themselves for classification into three groups. The first group [1] involves direct formation from open-chain compounds, usually 1, 3-di or 1, 3, 5-triketones[43]. Stavaux and Lozac'h[44] have, for example, prepared a variety of substituted trithiapentalenes (15) by treating 1, 3, 5-triketones (14) with phosphorus pentasulphide in refluxing



14 15

benzene. Syntheses from cyclic starting materials form the second group [2], which can be considered as two subgroups, the first [2a] using six-member rings and the second [2b] starting from five-member ring systems. In a synthesis of type [2a] Reid and



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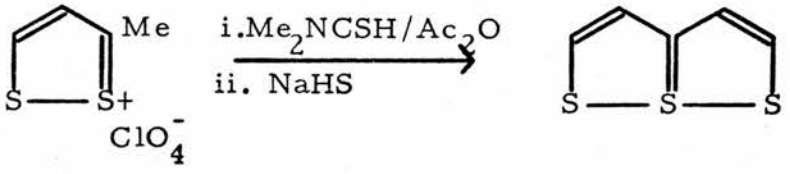
his co-workers[45] treated 4H-thiopyran-4-thione (16) with sodium sulphide and then with potassium ferricyanide and obtained 1, 6, 6aλ^4-trithiapentalene (17) in good yield. Reid et al.[46] have also obtained compound (17) by treatment of 3-methyl-1, 2-dithiolium perchlorate (18) with dimethylthioformamide in acetic anhydride followed by



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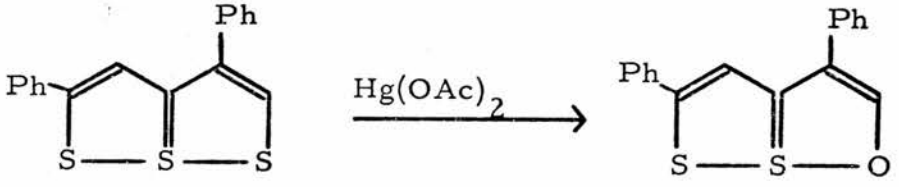
sodium hydrogen sulphide, an illustration of a synthesis of group [2b]. The third group of methods [3] can be called replacement reactions, and includes, for example, the mercuric acetate desulphurisation of the trithiapentalene (19) to give the oxadithiapentalene (20)[30,47] and the reaction of trithiapentalenes (15) with



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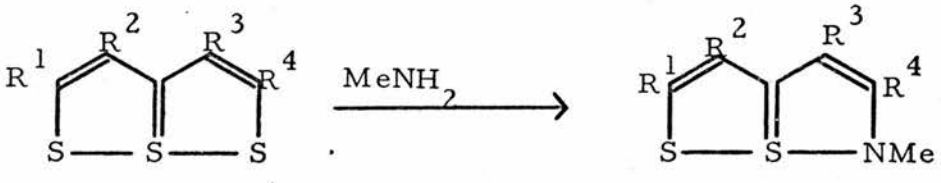

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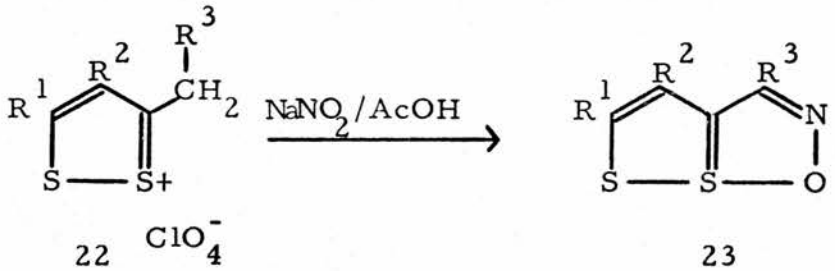
ethanolic methylamine to give dithia-azapentalenes(21)[48].

The known synthetic routes to 2-aza analogues of 1, 6, 6aλ^4-trithiapentalenes divide themselves between the types [2b] and [3] mentioned above. Those of type [2b] are the following.

Reid and his co-workers[20] have devised a method by which a variety of substituted 1-oxa-6, 6aλ^4-dithia-2-azapentalenes (23)

are available in high yield. It involves treatment of 3-methyl(ene)-



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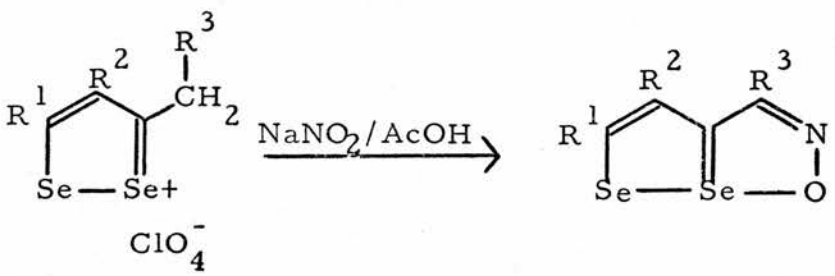
1,2-dithiolium perchlorates (22) with sodium nitrite in acetic acid. This is a more versatile synthesis than the original (type [3]) route to oxadithia-azapentalenes reported by Beer et al.[18], which involved direct nitrosation of 1,6,6aλ^4-trithiapentalenes. In the same paper[20], an extension of this method of Reid and co-workers to diselenolium perchlorates (24) gave 1-oxa-6,6aλ^4-diselena-2-



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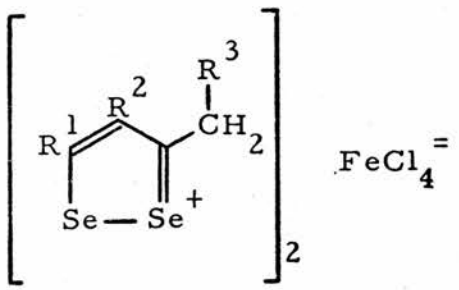
azapentalenes (25) in good yield. These diselenolium salts were prepared by a method adapted[49] from an earlier synthesis described by Heath and co-workers[50]. Reaction of 1,3-diketones with hydrogen selenide in ethanolic hydrogen chloride, and in the presence of iron III chloride, gave bis(1,2-diselenolium) tetrachloroferrates (II) (26). The tetrachloroferrate ion was exchanged for the perchlorate anion by treatment with perchloric acid in



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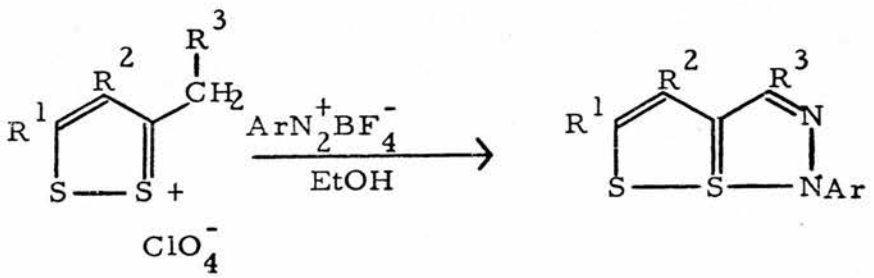
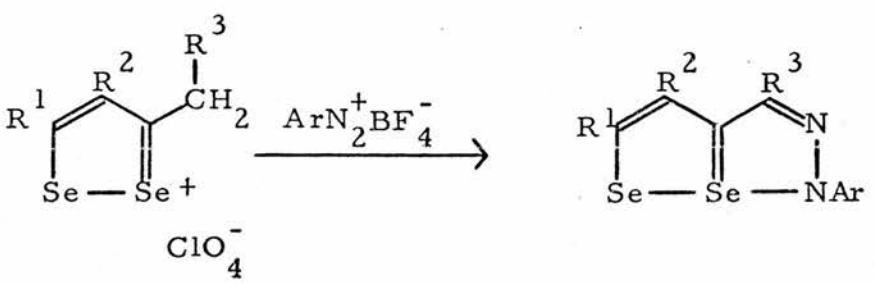
glacial acetic acid.

Related to the foregoing is the very useful synthesis of 6, 6a λ^4-dithia-1, 2-diazapentalene (27)[40,51] by reaction of



22 27

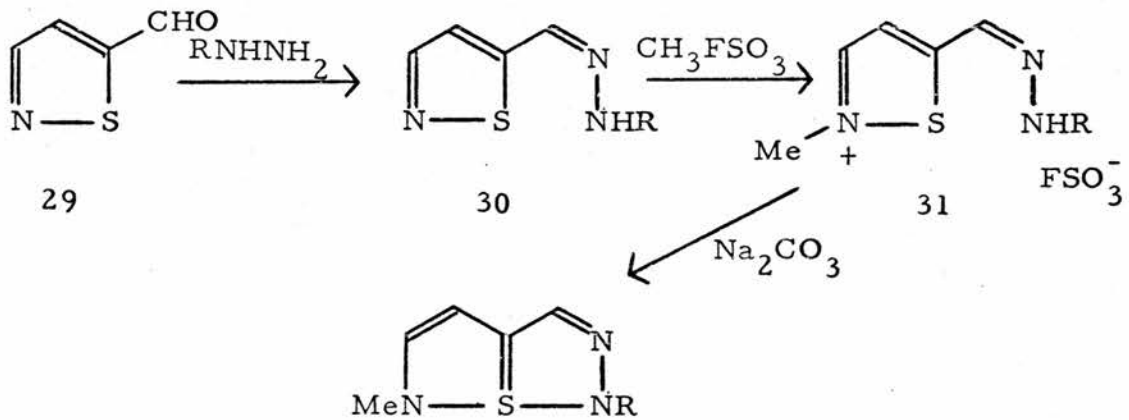
1, 2-dithiolium perchlorates (22) with arenediazonium tetrafluoroborates in hydrogen bonding solvents. Similar extension of this synthesis to diselenolium salts (24) provided modest yields of



24 28

6, 6a λ^4-diselena-1, 2-diazapentalenes (28)[40]. These syntheses all rely on the acknowledged[40] acidity of the protons of 3-methyl(ene) groups of 1, 2-dithiolium and 1, 2-diselenolium cations, and the mechanism has been well studied[40, 52].

A very recent addition to the type [2b] methods of synthesis is the preparation of various 6a λ^4-thia-1, 2, 6-triazapentalenes (32)[53] in three simple steps from 5-formylisothiazole (29), now a



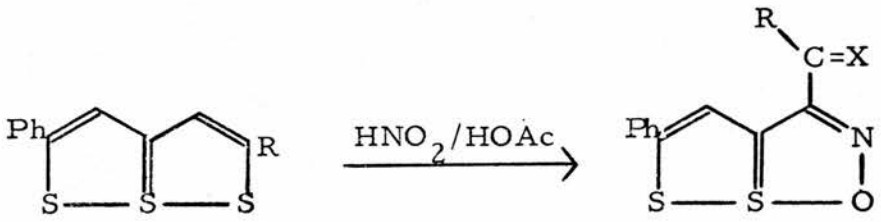
29 30 31

32

commercially available and virtually unexploited reagent. 5-Formylisothiazole (29) reacted with alkyl and aryl hydrazines to give the hydrazones (30), which were methylated using methyl fluorosulphonate to give the isothiazolium salts (31). Subsequent deprotonation by aqueous sodium carbonate gave the products (32) in good yield. This has some advantages over earlier (type [3]) routes[54] to the same system (see page 11).

The following type [3] syntheses of 2-aza analogues of 1, 6, 6a λ^4-trithiapentalenes have been reported.

The original route of Beer et al.[17,55] to the 1-oxa-6,6aλ^4-dithia-2-azapentalenes (34) involved nitrosation of 2-methylthio-5-phenyl and 2,5-diphenyl-1,6,6aλ^4-trithiapentalenes (33) with

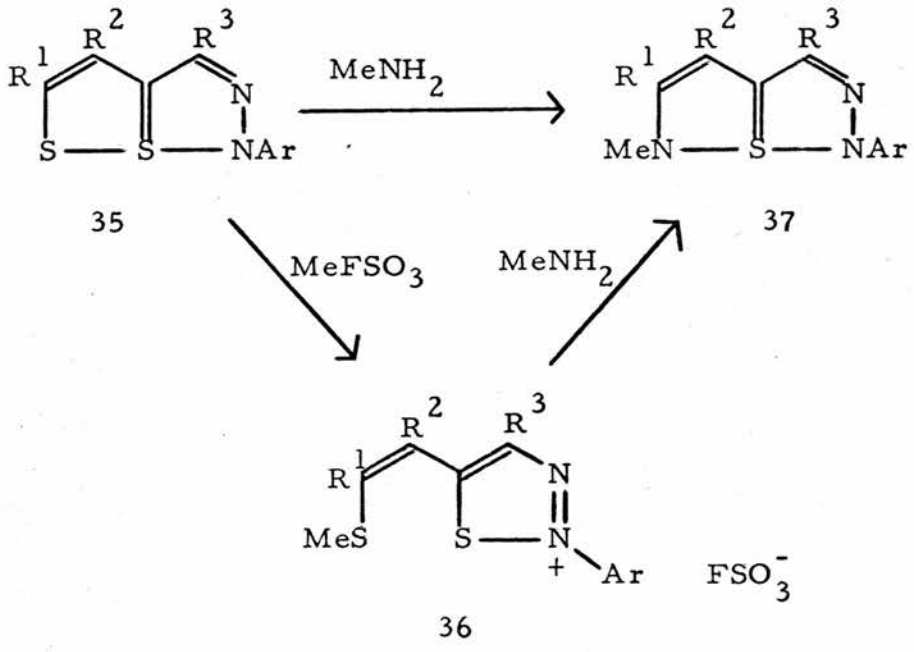


33a. R=SMe
b. R=Ph

34a. R=SMe, X=S
b. R=Ph, X=O

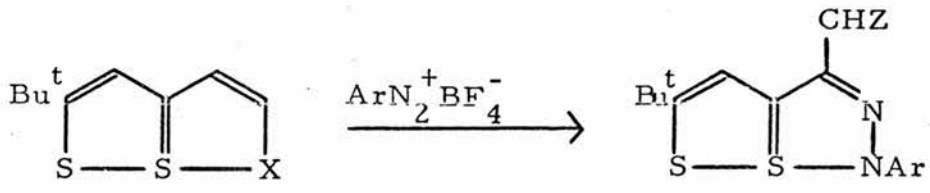
nitrous acid in acetic acid. Compound (33a) led to the dithioester (34a), and by a similar rearrangement accompanied by hydrolysis in situ of the unstable thioketo groups, compound (33b) gave the ketone (34b).

A variety of substituted 6aλ^4-thia-1,2,6-triazapentalenes (37) were first prepared[54] by treating 6,6aλ^4-dithia-1,2-diazapentalenes (35) with methylamine in dimethylformamide. The same study provided an alternative route involving initial methylation of dithiadiazapentalenes (35) to give the 1,2,3-thiadiazolium tetrafluoroborates (36), which were then treated with methylamine to give the products (37).



35 36 37

The first reported members of the 6, 6aλ^4-dithia-1, 2-diazapentalene system[51] were formed in the reaction of 2-t-butyl-1, 6, 6aλ^4-trithiapentalene (38, X=S), the 2-t-butyl-1, 6aλ^4-dithia-6-azapentalene (38, X=NMe) and 5-t-butyl-1-oxa-6, 6aλ^4-dithia-pentalene (38, X=O) with p-nitrobenzenediazonium tetrafluoroborate. In the first two of these cases, the groups thioformyl (Z=S) and iminomethyl (Z=NMe), resulting from initial electrophilic attack

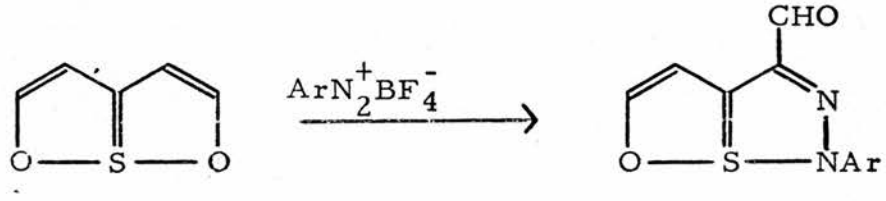


38 39

Ar=p-NO_2Ph

at C-4 by diazonium cation followed by rearrangement, undergo

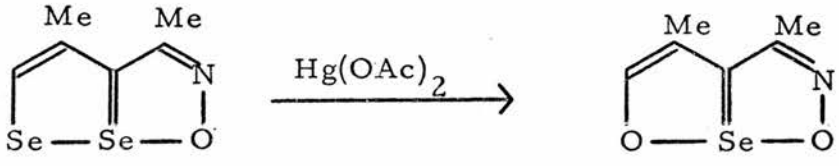
hydrolysis in situ to the aldehyde (39, Z=O), the same product obtained from the oxadithiapentalene (38, X=O). A further study of the reaction of arenediazonium tetrafluoroborates with 1-oxa-6, 6a λ^4-dithiapentalenes has been reported[56]. Treatment of 1, 6-dioxa-6a λ^4-thiapentalene (40) with p-nitrobenzendiazonium tetrafluoroborate gave the 6-oxa-6a λ^4-thia-1, 2-diazapentalene (41),



40 41

Ar=p-NO_2PH

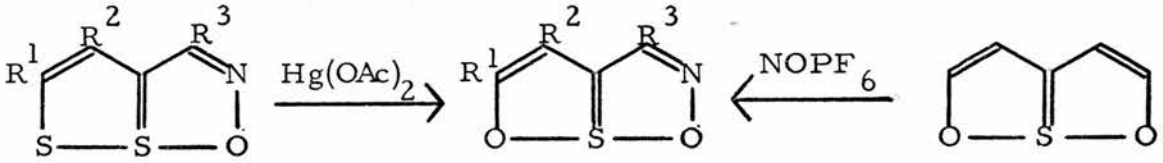
the first example of this system[51]. Another route[54] to this system by mercuric acetate desulphurisation of 6, 6a λ^4-dithia-1, 2-diaza-pentalenes is useful, but restricted to substrates blocked at position 3 to prevent electrophilic attack by mercuric acetate at this site. Similarly, mercuric acetate deselenisation of the 1-oxa-6, 6a λ^4-diselena-2-azapentalene (42) in boiling acetic



42 43

acid gave a good yield of the 1, 6-dioxa-6a λ^4-selena-2-azapentalene (43)[57].

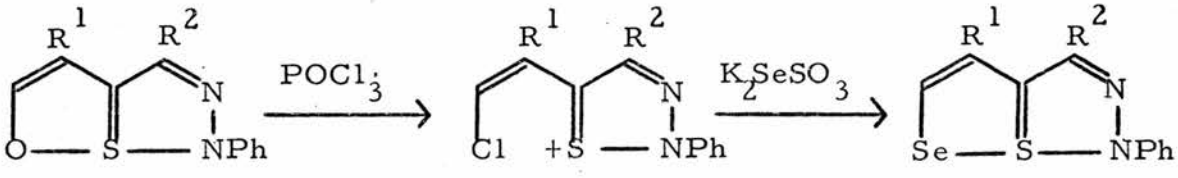
1,6-Dioxa-6a λ^4-thia-2-azapentalenes (46) also have been prepared by mercuric acetate desulphurisation[57], this time



44 46 45

of 1-oxa-6,6a λ^4-dithia-2-azapentalenes (44), but the first reported[52] member of this system (46, R^1=R^2=H, R^3=CHO) was obtained in excellent yield by treatment of 1,6-dioxa-6a λ^4-thia-pentalene (45) with nitrosyl hexafluorophosphate ($NOPF_6$) in methylene chloride, in the presence of an excess of calcium carbonate.

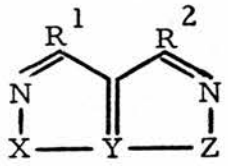
6a λ^4-Thia-6-selena-1,2-diazapentalenes (49) have been prepared[53] in good yield by the reaction of 5-chlorovinyl-1,2,3-



47 48 49

thiadiazolium salts (48) with aqueous potassium selenosulphate. These 5-chlorovinyl-1,2,3-thiadiazolium salts (48) were prepared in situ by treatment of oxathiadiazapentalenes (47) with phosphoryl chloride in dimethylformamide.

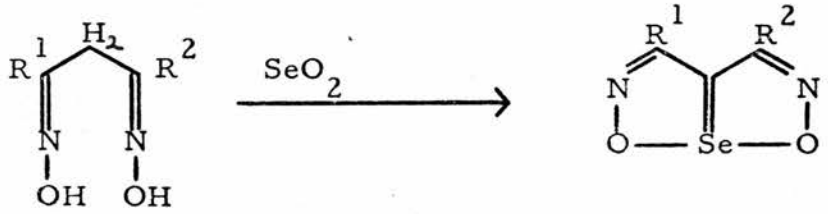
In contrast to the above, most syntheses of the closely related systems (50) use open-chain precursors. These



50

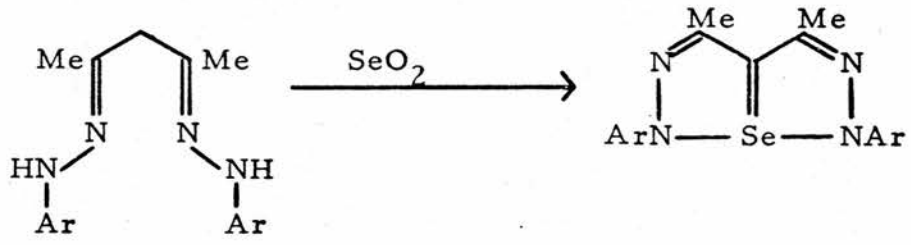
X, Z=O, S, NAr; Y=S, Se, Te

syntheses thus fall into group [1]. Vialle and his co-workers[58] have investigated some earlier work[59] and prepared a series of substituted 1, 6-dioxa-6a λ^4-selena-2, 5-diazapentalenes (52) by the



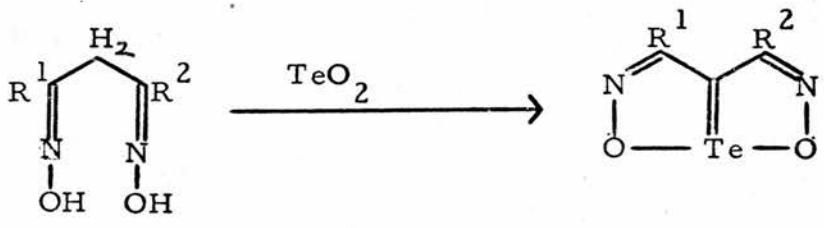
51 52

reaction of the dioximes (51) of various 1, 3-diketones with selenium dioxide (SeO_2). An extension[60] of this work led to the isolation of the 6a λ^4-selena-1, 2, 5, 6-tetra-azapentalene (54) from the reaction of the bis(2, 4-dinitrophenylhydrazone) (53) of 2, 4-pentanedione with selenium dioxide. Several 1, 6-dioxa-6a λ^4-tellura-2, 5-diazapentalenes (55) were also prepared[60] by treatment of



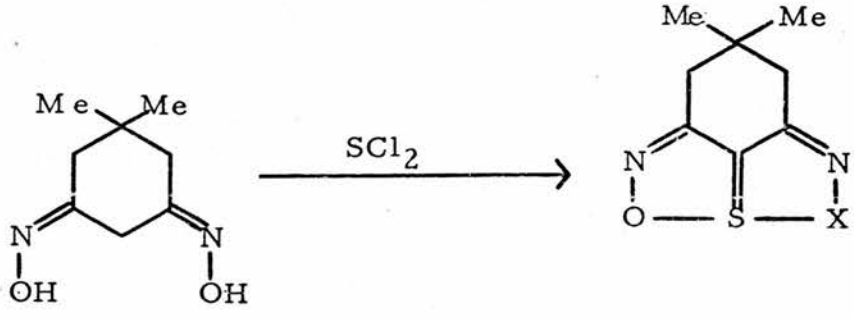
53 Ar=2,4-dinitrophenyl 54

dioximes (51) of 1,3-diketones with tellurium dioxide (TeO_2).



51 55

Beer et al.[42] have prepared the first sulphur analogues (57) of these systems by treatment of dimedone dioxime (56) with sulphur dichloride.



56

57a. X=O
b. X=S

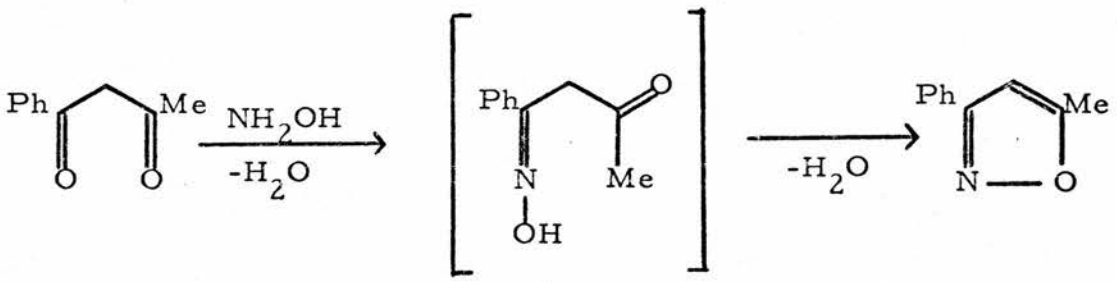
2. Introduction of the =N—S Unit into Heterocyclic Systems

(a) Oximes and Nitroso Compounds: Their Use in the Synthesis of Heterocycles Containing the =N—O Unit

Oximes (59) are isomers of primary or secondary nitroso compounds (58), of which few are known[61]. Oximes and nitroso

58 59

compounds offer themselves as logical and convenient precursors for the synthesis of heterocyclic systems containing the =N—O moiety. It has been known for a long time[62,63] that the oxime groups is present in intermediates [e.g. (61)] in various general syntheses of

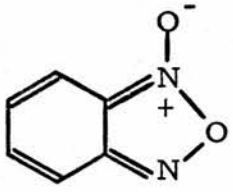


60 61 62

isoxazoles [e.g. (62)], for example, in the reaction of hydroxylamine with 1,3-dicarbonyl compounds [e.g. (60)], and various structures of the isoxazole type have been prepared by dehydrating oximes themselves.[61,62,58,60,42]

Also, it is known that o-dinitrosobenzene exists in the form (63) rather than the form (64), and the exocyclic oxygen atom is

migratory[61].



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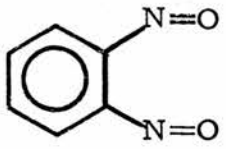

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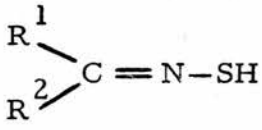
(b) Thio-oximes and Thionitroso Compounds: Their Potential Synthetic Utility

In the light of the discussion in (a) above it seems reasonable that thio-oximes (65) and thionitroso compounds (66) would be useful



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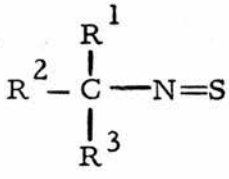
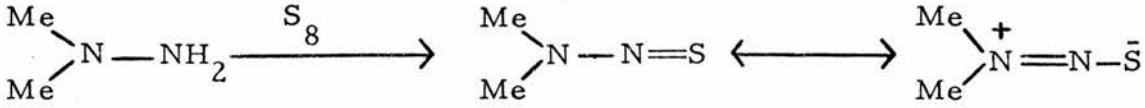


66

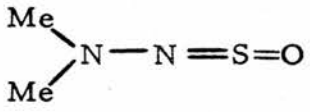
precursors in the synthesis of heterocycles containing the =N—S unit. However, while knowledge of the chemistry of oximes and nitroso compounds is well advanced, the chemistry of their thio analogues is still in its infancy, and thio-oximes and thionitroso compounds have not yet been used in heterocyclic synthesis.

Middleton[64] prepared the first authentic thionitroso compound, N-thionitrosodimethylamine (67), by the reaction of 1,1,-dimethyl-hydrazine with a suspension of elemental sulphur in ether. The same



67a 67b

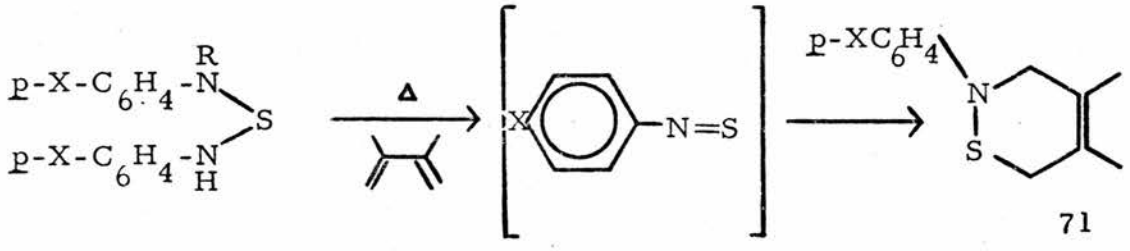
product was obtained in similarly low yield on treatment of thionyldimethylhydrazine (68) with lithium aluminium hydride in ether. Samples of compound (67) decomposed within a few hours



68

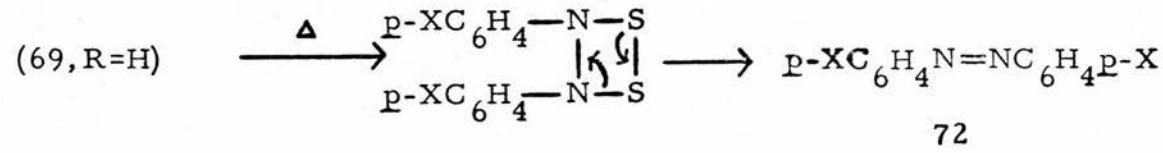
at room temperature. N-Thionitrosopiperidine and N-thionitrosohexahydro-1H-azepine were both prepared but it was not found possible to isolate them in analytically pure form. Evidence was provided which suggested the importance for the stability of these compounds of the dipolar thio-oximate species (67b).

At about the same time, Tavs[65] assumed the existence of the thionitroso species (70) in the reaction of the N,N'-thiodianilines



69 70 71

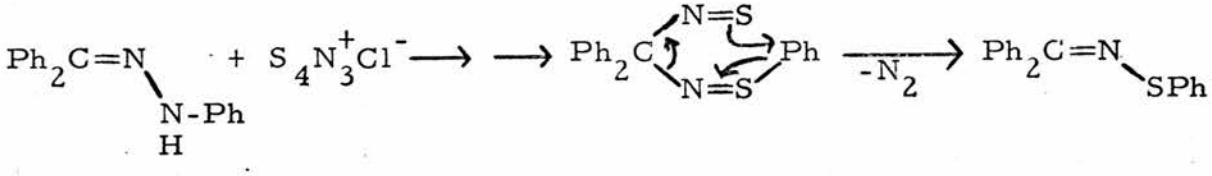
(69, X=H, Cl, Br; R=H) with 2,3-dimethylbutadiene, which resulted in the cyclic product (71). Minami and his co-workers[66] have provided support for this claim by apparently trapping the same intermediate (70, X=H) from the reaction of a more complex compound (69, X=H; R=MeHC=CPhCO—) with 2,3-dimethylbutadiene. More recently, Davis and Skibo[67] have suggested the dimerisation of two thionitroso



72

intermediates of the same type to account for the formation of the azobenzenes (72) in the thermal decomposition of the N,N'-thiodianilines (69, R=H; X=OMe, H, Br, Cl) and the analogous 3,3'-dinitro compound (X=H).

Barton and Bubb[68], in a very recent report, have postulated the existence of a thionitroso intermediate [e.g. (74)] in several of their reactions. For example, such an intermediate is invoked to



73 74 75

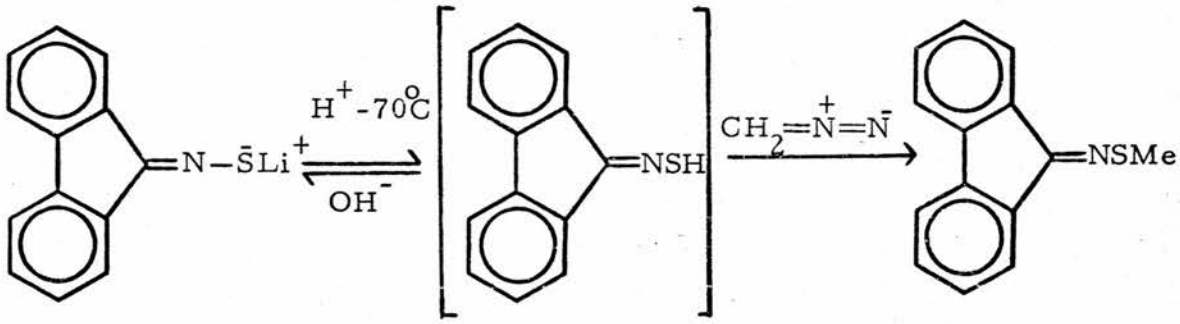
explain the formation of N-(phenylthio)diphenylmethylenamine (75) in the reaction of benzophenone phenylhydrazone (73) with thiotrithiazyl chloride ($S_4N_3^+Cl^-$).

Barton et al.[69], in an attempt to prepare 1-dimethylamino-4-thionitrosobenzene (76, X=S) by treatment of N,N-dimethyl-p-nitrosoaniline (76, X=O) with phosphorus pentasulphide, obtained instead the

76

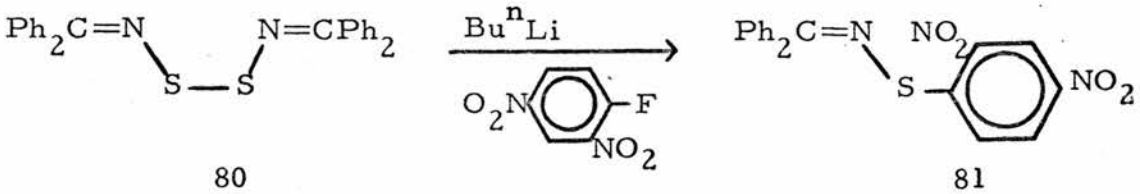
product (76, X=S=S) which contains the new functional groups —N=S=S and seems relatively stable.

True thio-oximes remained unknown until Barton and his co-workers[70] provided evidence for the existence of the species (78)



77 78 79

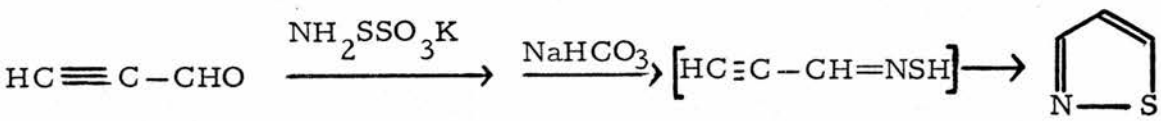
in solution below -70°C. Treatment of the salt (77) with acetic acid at -70°C gave a pale yellow solution which reacted with diazomethane to give the methylthioimine (79). The salt (77) was regenerated on addition of aqueous KOH to the yellow solution at -70°C. Simultaneously Hudson et al.[71] reported the generation of a thio-



80 81

oximate anion when n-butyl lithium was used to induce S—S cleavage of the disulphide (80). The thio-oximate ion, once formed, was trapped by 2,4-dinitrofluorobenzene, which was present in the reaction mixture, as N-(2,4-dinitrophenylthio)diphenylmethylenamine (81). The report[71] concludes that the thio-oximate anion formed is

sufficiently stable to be used for reactions in situ. Buttimore and Slack[72] have postulated that a thio-oxime (82) is a transient intermediate in their synthesis of isothiazole.



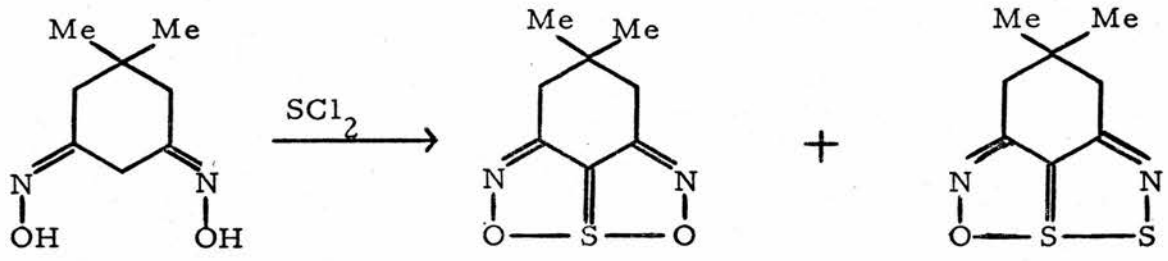
82

A variety of S-substituted thioimino compounds (=N—SR) have been prepared, and the subject is well reviewed[73-76].

The potential utility of thionitroso compounds and thio-oximes for introduction of the =N—S unit into structures of the 1, 6, 6a λ^4-trithiapentalene type (compare oximes, references 42, 58, 60) is of special relevance to the work presented in this thesis, and warrants an examination to which it has not yet been subjected.

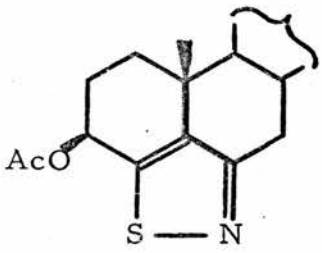
(c) Other Methods of Introducing the =N—S Unit into Heterocyclic Systems

Most heterocycles containing the =N—S moiety are of the isothiazole type and are prepared by a wide variety of methods which have been extensively reviewed[77, 78-80]. In this light it is interesting that, with the following single exception, the presence of the =N—S unit in a structure of the 1, 6, 6a λ^4-trithiapentalene type remains unreported in the literature. Beer and Poole[42] have reported the isolation of the 1-oxa-6, 6a λ^4-dithia-2, 5-diazapentalene (57b) as a byproduct in low yield from the reaction of dimedone dioxime (56) with sulphur dichloride, which gives compound (57a) as the main product.



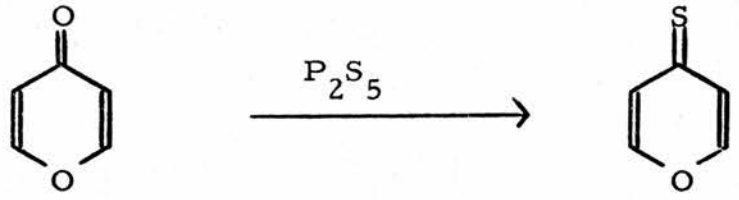
56 57a 57b

Barton and Bubb[68] have recently claimed the synthesis of heterocycles containing the =N—S unit during their investigation of the utility of S_4N_4, S_4N_3Cl, $S_3N_3Cl_3$, and S_4N_2 as reagents for preparing compounds containing nitrogen-sulphur bonds. For example, they have proposed that the product from treatment of cholesteryl acetate with $S_3N_3Cl_3$ in the presence of pyridine is compound (83).



83

The use of phosphorus pentasulphide as a reagent to effect replacement of oxygen by sulphur in organic compounds is well known[81, 82]. For example, 4H-pyran-4-thione (85) is prepared by treating 4H-pyran-4-one (84) with phosphorus pentasulphide[83],



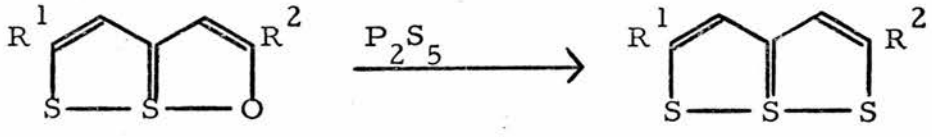
84 85

and thioamides (86) are frequently prepared by treating amides

$$RCONH_2 \xrightarrow{P_2S_5} RCSNH_2$$

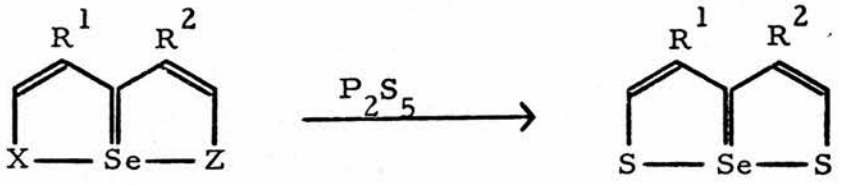
86

with phosphorus pentasulphide[84]. Therefore this reagent has received much use in studies of reactions of oxa analogues of trithiapentalenes and in various related syntheses. One of the first preparations of 1, 6, 6a λ^4-trithiapentalenes(88) involved



87 88

initially the formation of 1-oxa-6, 6a λ^4-dithiapentalenes(87) and subsequently their thionation using P_2S_5[43]. Further, lateral oxygen and selenium atoms in various 6a λ^4-selenapentalenes are readily replaced by sulphur by using phosphorus pentasulphide[49]. Treatment of mixtures of the 1, 6, 6a λ^4-triheterapentalenes (89) with



89 90

X, Z = O, S, Se

P_2S_5 gave the corresponding 1, 6-dithia-6a λ^4-selenapentalenes (90)[49].

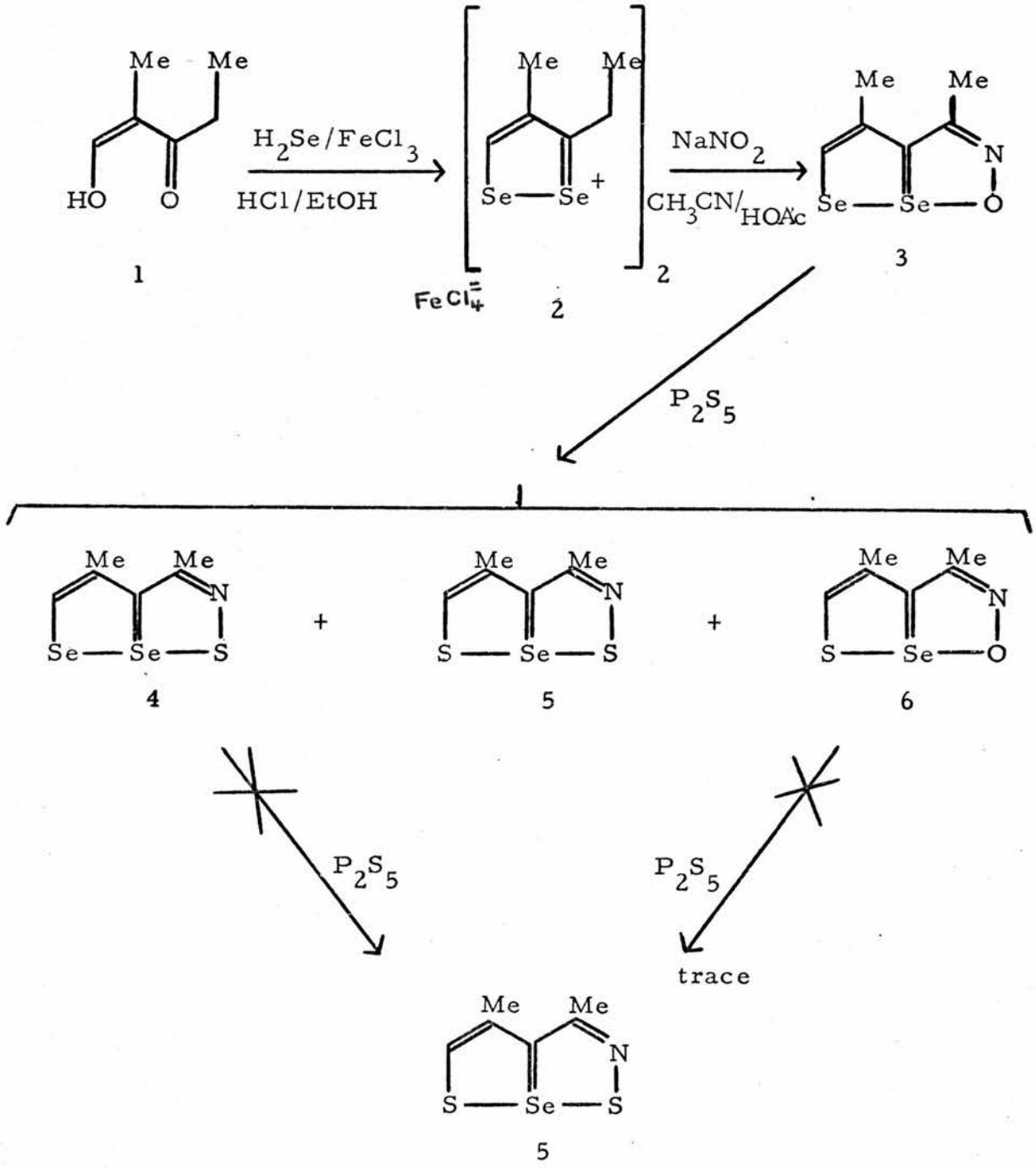
The use of phosphorus pentasulphide for the preparation of structures of the trithiapentalene type containing the =N—S unit would require the replacement of an oxygen atom attached to nitrogen. This process has not yet been reported in the literature.

DISCUSSION OF RESULTS

1. Thionation of 3,4-Dimethyl-1-oxa-6,6aλ^4-diselena-2-azapentalene and 4,5-Dihydro-3H-benzo[cd]-1-oxa-6,6aλ^4-dithia-2-azapentalene using Phosphorus Pentasulphide

(a) Thionation of 3,4-Dimethyl-1-oxa-6,6aλ^4-diselena-2-azapentalene

The possibility of using phosphorus pentasulphide to effect replacement of oxygen by sulphur in a structure of the trithiapentalene type, as a route to new systems containing the =N—S unit, has been discussed. (see subsection 2.c of the Discussion of Background Literature). This type of exchange of an oxygen atom attached to a nitrogen atom constitutes a type [3] synthetic method and has not hitherto been reported. Lateral oxygen and selenium atoms in many 6aλ^4-selenapentalenes are easily replaced by sulphur on treatment with phosphorus pentasulphide (see subsection 2.c of the Discussion of Background Literature), and it was considered that 3,4-dimethyl-1-oxa-6,6aλ^4-diselena-2-azapentalene (3) would be a suitable starting material for our purpose. The synthesis of this type of system from 1,2-diselenolium perchlorates has been mentioned in the previous section (subsection 1.c), but the conversion of the tetrachloroferrate (II) salt (2) into the corresponding perchlorate before nitrosation was omitted in the present work, and a small increase in overall yield of compound (3) resulted.



2-Hydroxymethylene-pentane-3-one (1), prepared from diethyl ketone and ethyl formate according to the procedure used for 2-hydroxymethylene-cyclohexanone[85], gave bis(3-ethyl-4-methyl-1,2-diselenolium)tetrachloroferrate (II) (2) on treatment with hydrogen selenide in ethanolic HCl, in the presence of iron (III) chloride[49]. This diselenolium salt (2) was nitrosated directly,

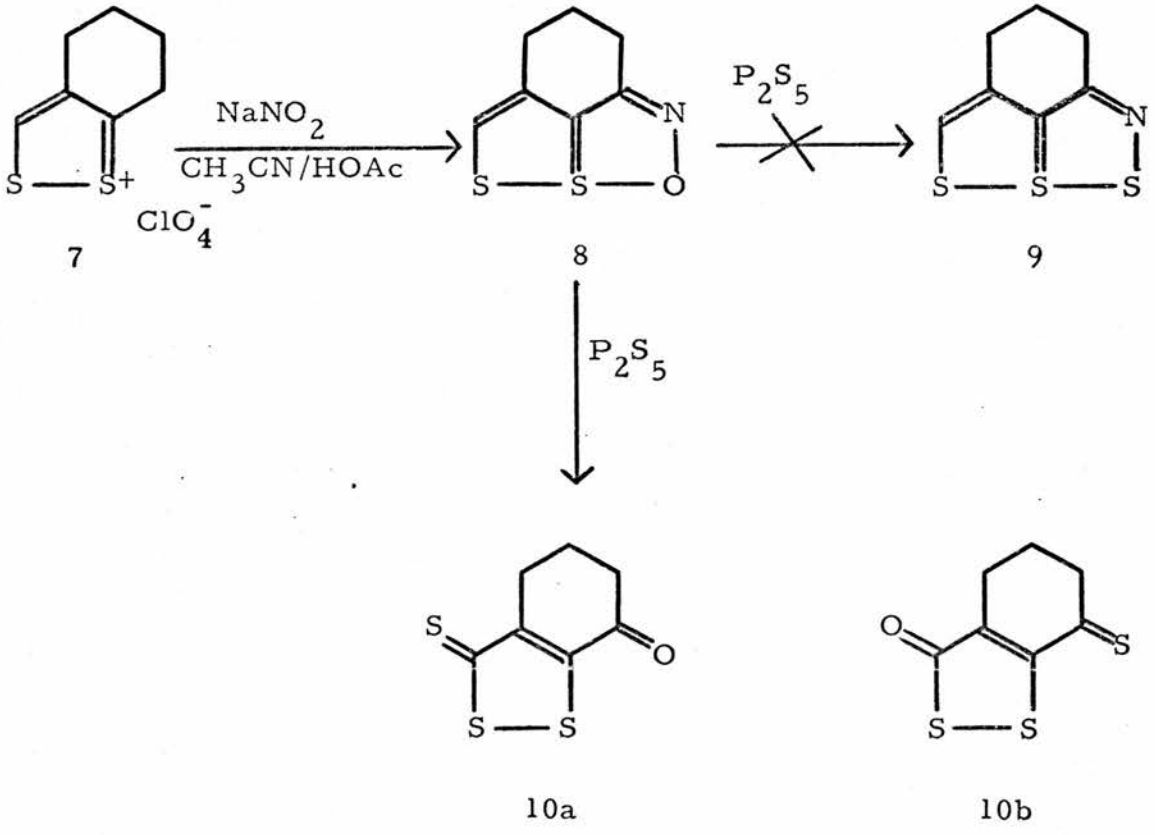
using sodium nitrite in acetonitrile/acetic acid, by a method adapted from the original procedure[20,49], and gave 3,4-dimethyl-1-oxa-6,6a λ^4-diselena-2-azapentalene (3) in 54% yield.

The oxadiselena-azapentalene (3) was treated with phosphorus pentasulphide in refluxing benzene, and repeated chromatography of the product mixture gave 3,4-dimethyl-1-thia-6,6a λ^4-diselena-2-azapentalene (4), 3,4-dimethyl-1,6-dithia-6a λ^4-selena-2-azapentalene (5), and 3,4-dimethyl-1-oxa-6-thia-6a λ^4-selena-2-azapentalene (6), in 12.1, 1.4, and 8.9% yields, respectively. Separation of the two less polar products, (4) and (5), was particularly difficult and required repeated chromatography on silica gel with petroleum spirit as eluant. While the low efficiency of the reaction appears to render it unsatisfactory as a general preparative procedure, the results are very significant in that all three products are representatives of new heterocyclic systems, and two of them, (4) and (5), contain the desired =N—S unit. The third product (6) is the first derivative of a four-electron three-centre bonded system containing four different heteroatoms. No starting material carried through with the products and a large percentage of it thus remains unaccounted for. It seems unlikely that the dithionated product (5) results from direct thionation of either compound (4) or (6) after they have been formed in the reaction. Pure samples of the thiadiselena-azapentalene (4) and the oxadiselena-azapentalene (6) were treated with phosphorus pentasulphide under the same conditions as used in their synthesis, and only in the latter case was there produced a trace of the dithiaselena-azapentalene (5)

sufficient for identification by accurate mass determination. The starting materials, (4) and (6), have uv and ^{1}H nmr spectra which resemble those of the oxadiselena-azapentalene (3).

(b) Thionation of 4,5-Dihydro-3H-benzo[cd]-1-oxa-6,6aλ^4-dithia-2-azapentalene

The usefulness of the thionation procedure of section (a) was further evaluated by an attempt to form the =N—S unit starting with 4,5-dihydro-3H-benzo[cd]-1-oxa-6,6aλ^4-dithia-2-azapentalene (8). Compound (8) was prepared in 88.5% yield from the dithiolium



7 8 9

10a 10b

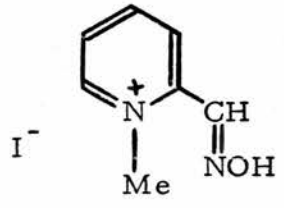
perchlorate (7) by reaction with sodium nitrite in acetonitrile/acetic acid (1:1) according to the procedure of Reid et al.[20].

However, there was no sign of the expected product (9) when the oxadithia-azapentalene (8) was treated with phosphorus pentasulphide. Instead, a product tentatively identified (^{1}H nmr, accurate mass, and C,H,O,S analysis) as (10a) or (10b) was isolated in 2% yield, accompanied by a small amount (7%) of starting material. No attempt was made to determine which isomer, (10a) or (10b), was obtained, and the mechanism by which such a product could arise is not clear. Again, a large proportion of the substrate (8) remains unaccounted for.

Although partial success was achived in the thionation of 3,4-dimethyl-1-oxa-6,6aλ^4-dithia-2-azapentalene (3) with phosphorus pentasulphide, the low yields obtained and the failure of the procedure in the case of 4,5-dihydro-3H-benzo[cd]-1-oxa-6,6aλ^4-dithia-2-azapentalene (8) are sufficient to confirm the limited synthetic value of this procedure.

2. 6-Methyl-1-oxa-6a λ^4-thia-2, 6-diazapentalene and Related Compounds

Pyridine-2-aldoxime methiodide (11), (P2-AM), and other pyridinium aldoximes are known effectively to reactivate acetylcholinesterase which has been inhibited by an organophosphorus



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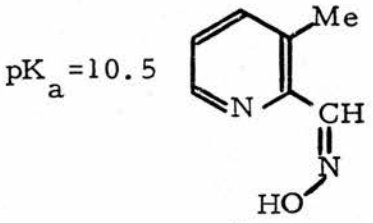
poison[86, 87]. These aldoximes appear to accelerate the hydrolysis of the phosphorylated enzyme, thus freeing the enzyme to perform its proper function. Benschop and his co-workers[88] have reported a study of acetylcholinesterase reactivation by oximes of isothiazole-carboxaldehydes and their ring N-methylated derivatives. Of special interest to the present work was the observation by Benschop *et al.* of the abnormally large increase in the acidity of isothiazole-5-carboxaldoxime (17) on methylation at N-2. Normally pyridine aldoximes [*e.g.* (12)] undergo a decrease in pKa of approximately one to two units on quaternisation (13)[89]. The change in pKa of *E*-isothiazole-3-carboxaldoxime (14) on quaternisation (15) was of this order (ΔpKa=2.2)[88]. Methylation of *Z*-isothiazole-5-carboxaldoxime (17), however, caused a decrease in pKa of 6 units. A promised[88] paper dealing with the reason for the exceptional acidity of the tosylate (18) has not been forthcoming[90].



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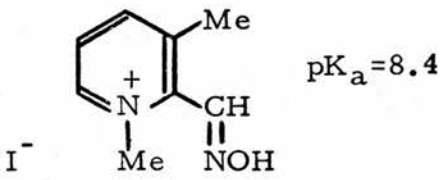

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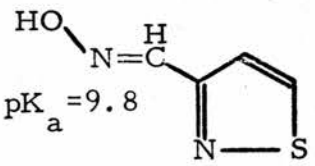

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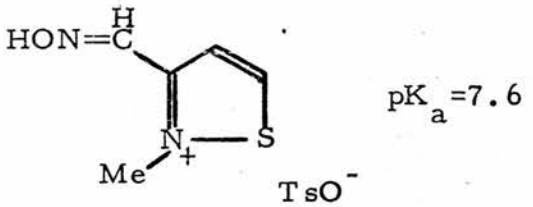

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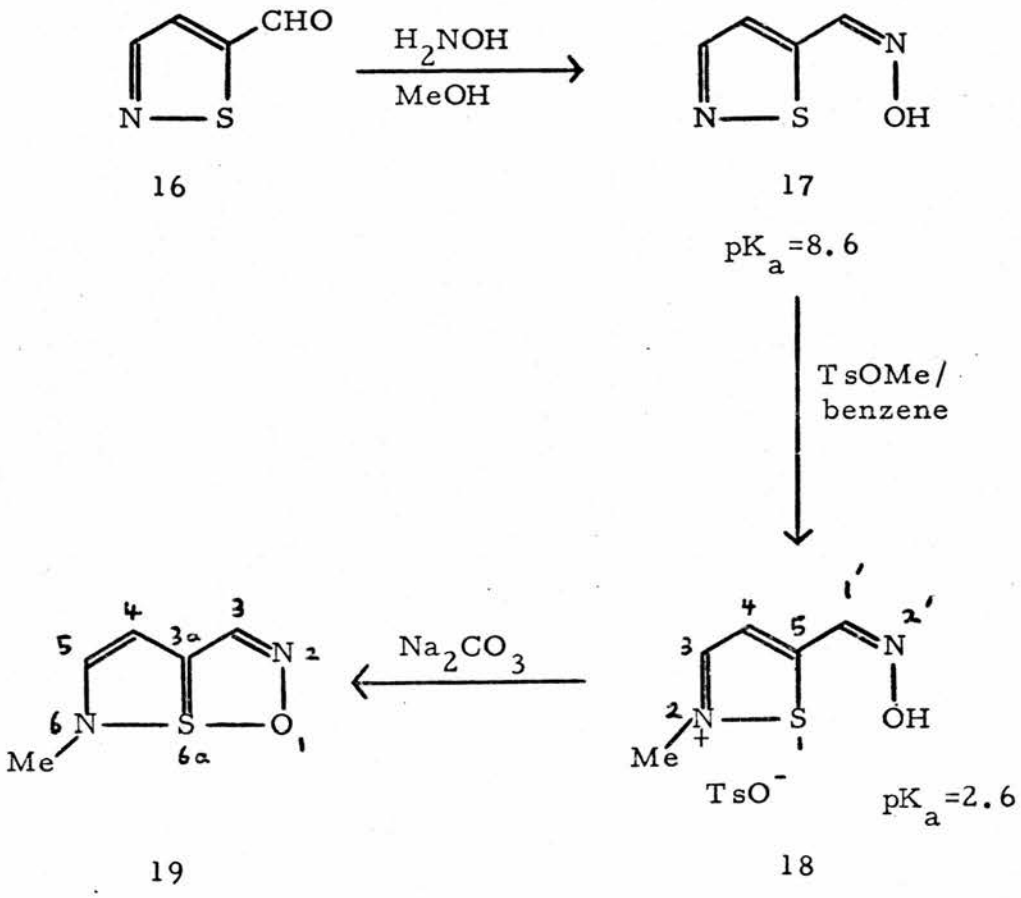
Benschop et al.[88] prepared 5-hydroxyiminomethyl-2-methylisothiazolium tosylate (18) in 8.6% yield by the reaction of the configurationally pure Z isomer of the oxime (17) with methyl p-toluenesulphonate (methyl tosylate). Although the configuration of (18) is not assigned in the report it is reasonable to assume that it remained Z, and it is shown as such in the accompanying formula (18).

We suspected that the high acidity of this oxime (18) is due to the formation of a stable bicyclic four-electron three-centre bonded structure following deprotonation, and establishing the truth of this has led to our isolation of 6-methyl-2-oxa-6a λ^4-thia-2,6-diazapentalene (19), the first and parent member of a new class

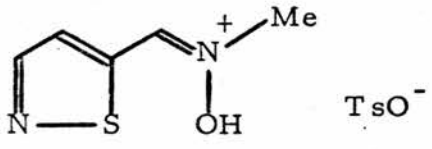


of heterocyclic system. We also intended to thionate compound (19) in order to give the 1-thia analogue, a novel system containing the =N—S unit. However, the low overall yield of (19) has precluded this pursuit.

Isothiazole-5-carboxaldoxime (17) was prepared in high yield by treating 5-formylisothiazole (16), a commercially available compound, with hydroxylamine in refluxing aqueous methanol. The ^{1}H nmr spectrum of the crude product, by comparison with the data of Benschop et al.[88], revealed that it was a 7:1 mixture of the Z and E isomers, respectively. (Benschop and co-workers report 9:1.) Recrystallisation from benzene gave

an 88% yield of oxime depleted in the E isomer. Benschop et al.[88] have commented on the apparent ease with which this E isomer is converted to the Z isomer.

The oxime (17), almost completely the Z isomer, was methylated by refluxing with methyl tosylate in benzene. The crude oily solid obtained was recrystallised from ethanol, yielding a product shown by ^{1}H nmr to be a mixture of the expected 5-hydroxyiminomethyl-2-methylisothiazolium tosylate (18) and the isomeric salt (20) resulting from methylation at N-2'. The tosylates (18) and



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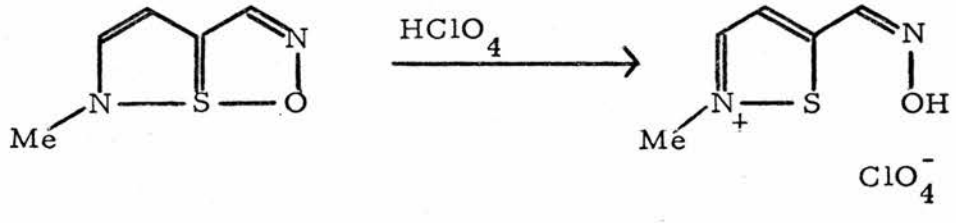
(20) were found to be separable by fractional crystallisation from acetonitrile. Evidence confirming both structure assignments was obtained from ^{1}H nmr spectral data. The 3-H, N-Me coupling constant in the tosylate (18) is 0.7 Hz, and the same value is observed for the 1'-H, N-Me coupling constant in the isomer (20). Of particular interest is the retention in compound (20) of the 3-H, 4-H coupling constant ($J_{3,4}$=2.0 Hz) characteristic of the isothiazole system, whereas quaternisation of the ring nitrogen increases J for the same two protons to 3.1 Hz. There was no evidence for the presence of geometrical isomers of either salt, and both are assumed to be Z (shown) since the oxime precursor was predominantly that isomer. Benschop and his co-workers[88] did not detect the presence of the isomeric 5-(N-methyl-N-

hydroxyiminomethyl)isothiazole tosylate (20). Our yield of the salt (18) was comparable (9.1%) to that obtained by Benschop *et al.* .

Deprotonation of the tosylate (18) with sodium carbonate and subsequent sublimation gave a virtually quantitative yield of 6-methyl-1-oxa-6aλ^4-thia-2,6-diazapentalene (19). With the neutralisation of the positive charge in the ring (18), the inductive deshielding effect on nearby protons is reduced, so that the 4-, 5-, and methyl protons of compound (19) all resonate at higher field in the ^{1}H nmr spectrum than do the corresponding protons in the precursor salt (18). The development of a significant ring current in the new molecule (19) is the probable cause of the small paramagnetic shift of the 3-H resonance. Also, $J_{4,5}$=3.6 Hz in the new bicyclic structure. (see Table 1.)

Treatment of 6-methyl-1-oxa-6aλ^4-thia-2,6-diazapentalene (19) with aqueous perchloric acid in methanol gave a high yield (93%) of the salt (21).



19 21

The ultraviolet spectra of methanol solutions of the oxathiadiazapentalene (19) and the salt (21) are virtually identical and show significant maxima at 216 nm and 334 nm. This indicates that the cation of the salt (21) is sufficiently acidic to deprotonate in

TABLE 1

^{1}H NMR CHEMICAL SHIFTS (δ) OF 5-HYDROXYIMINOMETHYL-2-METHYLISOTHIAZOLIUM TOSYLATE (18) AND 6-METHYL-1-OXA-6aλ^4-THIA-2,6-DIAZAPENTALENE (19)

solvent - dmso-D_6, TMS internal reference

(b = broad, s = singlet, d = doublet, q = quartet)

	(18)			(19)	
1'-H	8.97 bs	$J_{1',4}$=0.5 Hz	3-H	9.08 s	
4-H	7.88 d	$J_{3,4}$ = 3.1 Hz	4-H	7.43 d	$J_{4,5}$=3.6 Hz
3-H	9.09 dq	$J_{3,NMe}$=0.7 Hz	5-H	8.61 dq	$J_{5,NMe}$=0.7 Hz
N-CH_3	4.10 d		N-CH_3	3.74 d	

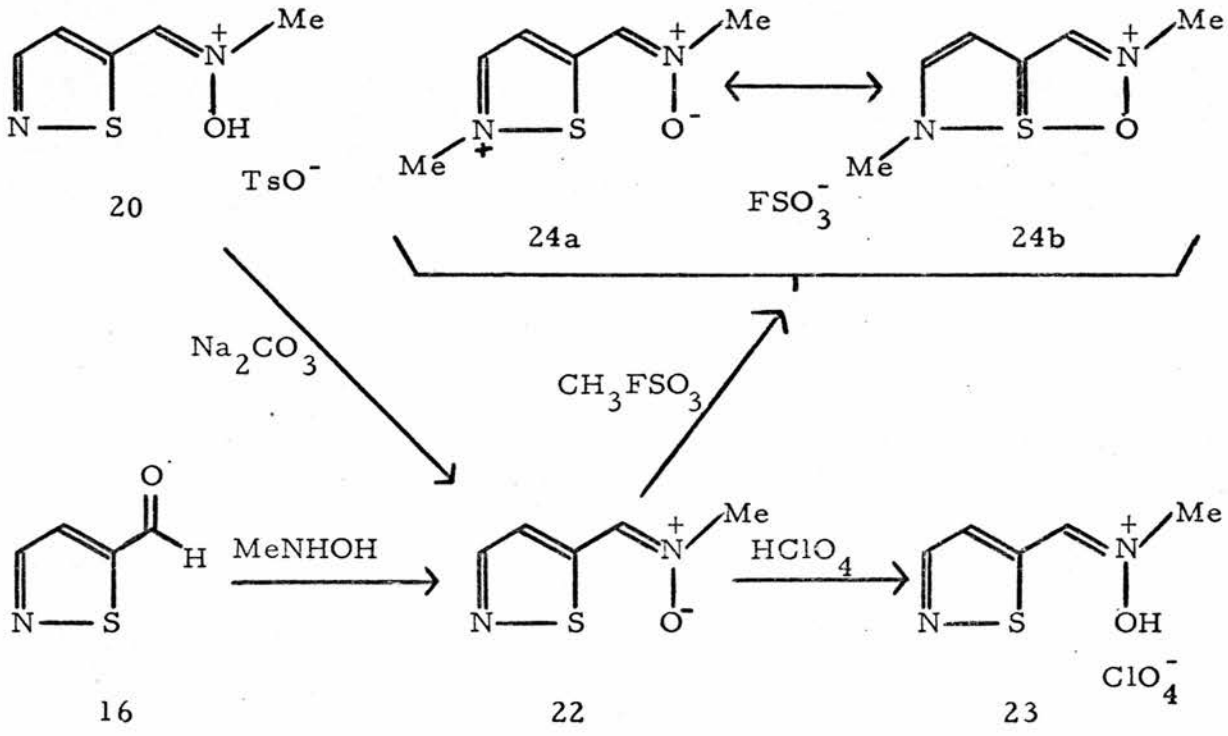
resonances for tosylate anion omitted

methanol resulting in the bicyclic structure (19). When the uv spectra of these two compounds, (19) and (21), are recorded using methanol solutions containing 1% of perchloric acid, the intense absorption at 216 nm is absent and the other major absorption, now at 301 nm, has undergone a hypsochromic shift of 33 nm. This is explained by protonation at oxygen, which destroys the 3-centre bonded bicyclic system.

When the ^{1}H nmr spectrum of the oxathiadiazapentalene (19) is recorded in trifluoroacetic acid solution, $J_{4,5}$ changes from 3.5 Hz (in dmso-D_6) to 3.1 Hz, the same as observed for the corresponding protons of the tosylate (18) (in dmso-D_6), indicating O-protonation and ring opening to an isothiazolium type structure.

The uv spectrum of the tosylate (18) in methanol is the same as that of the oxathiadiazapentalene (19) and the perchlorate (21) except for the major absorption at 218 nm, attributable to tosylate anion, and the absorption at 334 nm undergoes the same hypsochromic shift in 1% $HClO_4$/methanol.

We have also studied the deprotonation of the tosylate (20). Treatment of this salt with sodium carbonate gave a high yield of



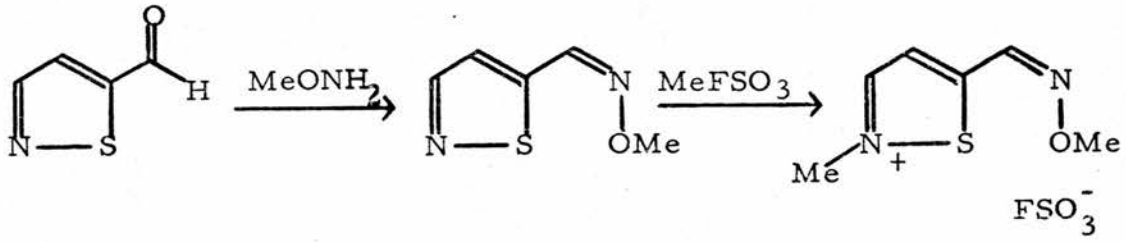
C-(5-isothiazolyl)-N-methylnitrone (22) (nomenclature, see ref. 91), but for investigative purposes a more practical route to this compound was the reaction of 5-formylisothiazole (16) with N-methylhydroxylamine, which gave the product (22) in almost quantitative yield.

The nitrone (22) reacted readily with perchloric acid, giving a virtually quantitative yield of the corresponding salt (23). It was evident from the ^{1}H nmr spectrum that protonation had not occurred at nitrogen (N—2), in that the spectrum of the product (23) displayed the same 3-H, 4-H) coupling constant ($\underline{J}_{3,4}$ = 2.0 Hz) as do the spectra of other compounds containing the isothiazole ring, namely compounds (16), (20) and (22). Protonation at the ring nitrogen atom would have changed $\underline{J}_{3,4}$ to 3.1 Hz [*cf.* the tosylate (18) and the perchlorate (21)]. A similar argument leaves no doubt that the product obtained on treatment of the nitrone (22) with methyl fluorosulphonate is not methylated at oxygen, since $\underline{J}_{3,4}$ = 3.2 Hz, and must therefore be the salt (24). Also, both $\underline{J}_{1',NMe}$ and $\underline{J}_{3,NMe}$ are observed, and are 0.7 Hz and 0.6 Hz, respectively. The salt (24) is interesting in that the bicylic form (24b) may be a significant contributing structure. As evidence for this it may be pointed out that the longest wavelength absorption in the uv spectrum of (24) occurs, not at 300 nm as observed for the nitrone (22), the tosylate (20), the protonated nitrone (23) and the isothiazolium salt (26) (see below), all of which are monocyclic, but rather at 331 nm, which is very close to the value of 334 nm observed for the oxathiadiazapentalene (19). The -1' proton in compound (24) is not noticeably acidic, as no proton exchange is observed when the ^{1}H nmr spectrum of the salt (24) is recorded in deuteriotrifluoroacetic acid.

The nitrone (22) and the perchlorate (23) both undergo protonation at N-2 in trifluoroacetic acid as evidenced by the change in their ^{1}H nmr spectra of $\underline{J}_{3,4}$ from 2.0 Hz (in dmso-D_6) to 3.1 Hz

in this solvent.

Other related derivatives of 5-formylisothiazole (16) were also prepared. Treatment of the aldehyde (16) with methoxyamine gave 5-methoxyiminomethylisothiazole (25) in 85% yield, as a 1:1



16 25 26

mixture (by ^{1}H nmr integration) of E and Z isomers (Z shown). The reaction of compound (25) with methyl fluorosulphonate gave 2-methyl-5-methoxyiminomethylisothiazolium fluorosulphonate (26) in good yield. This product appeared to be a single compound, and although a definite configurational assignment was not made it seems reasonable to assume that it is the Z isomer (shown). Methylation at the ring nitrogen is shown by the increase in $J_{3,4}$ from 1.8 Hz in the ^{1}H nmr spectrum of (25) to 2.9 Hz in the spectrum of the salt (26). Also, the 3-H, NMe and 4-H, 1'-H coupling constants are the same for this salt (26) as for the tosylate (18), being 0.7 Hz and 0.5 Hz, respectively.

EXPERIMENTAL

Introductory Notes

Melting points were determined on a Kofler hot-stage apparatus and are corrected.

Ultraviolet and visible spectra were measured with a Unicam SP800 spectrophotometer.(sh = shoulder, pl = plateau)

Mass spectra were obtained with an AEI MS902 instrument.

^{1}H Nmr spectra were recorded at ca. 31.4°C, unless otherwise stated, with a Varian HA100 spectrometer operating at 100 MHz. Solutions in deuteriochloroform and hexadeuteriodimethylsulphoxide (dmso-D_6) were 0.4 M unless otherwise stated. Chemical shifts (δ) are given in ppm downfield from tetramethylsilane as internal reference unless otherwise stated. J values were measured on the 100 Hz scale and multiplicity refers to the appearance of the spectra on this scale. The multiplicity symbols have their usual meanings (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, b = broad). Some coupling constants were obtained from spin-decoupled spectra.

Carbon, hydrogen and nitrogen elemental microanalyses were carried out by Mr. J.R. Bews of this department. Sulphur and oxygen microanalyses were carried out by Dr. A. Bernhardt, Mulheim, West Germany.

Criteria used in the identification of new products included melting point, t.l.c. behaviour, CHN analysis, and nmr and mass spectra, except where not possible.

Solutions were dried over anhydrous sodium sulphate and solvents were evaporated at reduced pressure with a rotary film evaporator. Solids were dried in vacuo over phosphorus pentoxide.

"Petrol" refers to petroleum ether of boiling range 40-60°C, and "ether" refers to diethyl ether. Petrol, acetic acid, n-hexane, cyclohexane, ethanol, methanol, toluene and xylene were all redistilled commercial solvents. Ether was dried over calcium chloride and distilled. Benzene for normal use, including chromatography, was dried by azeotropic distillation. Dry ether and dry benzene were obtained by refluxing the respective solvents over sodium wire and distilling. They were then stored over sodium wire.

Methylene chloride for extractions was washed with aqueous sodium bicarbonate and then with water, dried over sodium sulphate and distilled. The dry solvent was obtained by distilling twice after refluxing over phosphorus pentoxide.

Acetonitrile was dried by refluxing ca. 30 min. over sodium hydride /50% in paraffin dispersion (2g/l) and distilling. The distillate was then refluxed ca. 1 h over phosphorus pentoxide and distilled twice.

Dry carbon disulphide was obtained by refluxing the Analar grade solvent over phosphorus pentoxide and distilling twice.

Dry ethanol was obtained by dissolving sodium in ethanol (ca. 7.5g/l), adding ethyl succinate (ca. 25g/l) and refluxing for two hours. Dry ethanol was then distilled. Ethanolic hydrogen

chloride was prepared by saturating dry ethanol with hydrogen chloride.

Acetone for use in reactions was redistilled Analar grade acetone.

Methanol for ultraviolet/visible spectroscopy was redistilled Analar methanol. Cyclohexane for this purpose was spectrophotometric grade cyclohexane.

Aniline, methyl iodide, 5-formylisothiazole, and methyl fluorosulphonate were the redistilled commercial products.

t-Amyl alcohol was the commercial material distilled from sodium wire.

Perchloric acid refers to 70-72% (w/w) Analar perchloric acid.

Phosphorus pentasulphide for thionations was prepared as follows. A saturated solution of phosphorus pentasulphide in boiling dry carbon disulphide was filtered through a glass sinter funnel and evaporated to dryness on a rotary evaporator. The remaining solid was dried in vacuo over phosphorus pentoxide.

Alumina for column chromatography was Spence grade H (100-200 mesh), and silica gel was Sorbsil Silica Gel.

1. Thionations using Phosphorus Pentasulphide

(a) Preparation of 3,4-Dimethyl-1-oxa-6,6aλ^4-diselena-2-azapentalene

2-Hydroxymethylene-pentane-3-one (1), b.p. 50-60°C/18 mm Hg, (lit.[54] 60-65°C/20 mm Hg), was prepared from diethyl ketone and ethyl formate by adapting an established procedure for the synthesis of 2-hydroxymethylenecyclohexanone[85].

For the preparation of bis(3-ethyl-4-methyl-1,2-diselenolium)-tetrachloroferrate (II) (2) anhydrous ferric chloride ($FeCl_3$) (16.3 g, 100 mmol) and 2-hydroxymethylene-pentane-3-one (1) (17.122 g, 100 mmol) were dissolved in ethanolic hydrogen chloride (300 ml) and the solution was cooled to 0°C. Hydrogen selenide, generated in a stream of nitrogen by slowly dropping conc. hydrochloric acid-water (1:1, 243 ml) onto crushed Al_2Se_3 (58 g), was slowly bubbled through the solution with magnetic stirring. After 6 h the reaction mixture was diluted with ether (2 l) and the dark crystalline precipitate was filtered off and washed with benzene and ether. A slurry of the salt in benzene/ether was made, and the crystals were again filtered off and dried. Bis(3-ethyl-4-methyl-1,2-diselenolium)tetrachloro-ferrate (II) (2) (18.19 g, 36%) was obtained. (All filtrates and residues were washed with sodium hypochlorite solution before disposal, and apparatus was likewise washed before cleaning.)

3,4-Dimethyl-1-oxa-6,6aλ^4-diselena-2-azapentalene (3) was originally prepared by exchanging the tetrachloroferrate anion of the diselenolium salt (2) for the perchlorate anion using 70% (w/w) perchloric acid and subsequent nitrosation of the resulting

diselenolium perchlorate[20]. We omitted this step and nitrosated the bis-diselenolium tetrachloroferrate (2) directly. To a magnetically stirred slurry of the tetrachloroferrate (2) (6.759 g, 10 mmol) in acetonitrile/acetic acid (1:1, 500 ml) at room temperature was added sodium nitrite (2.761 g, 40 mmol). At the end of 10 min the reaction was diluted with water (2 l) and extracted with benzene (4 x 1 l). The extracts were washed with water (4 x 1 l) and dried. The solid remaining after evaporation of the benzene was dissolved in ether and chromatographed on alumina (40 x 5 cm). The ether eluates were evaporated to dryness and the solid was crystallised from cyclohexane, giving 3,4-dimethyl-1-oxa-6,6aλ^4-diselena-2-azapentalene (3) (2.888 g, 54%).

(b) Thionation of 3,4-Dimethyl-1-oxa-6,6aλ^4-diselena-2-azapentalene

Purified phosphorus pentasulphide (8.889 g, 40 mmol) was added to a solution of 3,4-dimethyl-1-oxa-6,6aλ^4-diselena-2-azapentalene (3) (5.340 g, 20 mmol) in dry benzene (300 ml), and the reaction was refluxed in an oil bath, with magnetic stirring, for 30 min. . A second reaction using phosphorus pentasulphide (8.890 g, 40 mmol) and the oxadiselena-azapentalene (3) (5.341 g, 20 mmol) was carried out simultaneously using the same procedure. After several minutes cooling both reactions were poured into the same 1 l water, which was then filtered by suction through a glass-wool plug into a separating funnel. The mixture was extracted with benzene (4 x 400 ml) and all the benzene used for

extraction was first drawn through the solid which had been filtered off, in order to obtain all possible product. The combined extracts were washed with water (4 x 500 ml), dried, and evaporated to low volume. This concentrated solution of products was divided into two equal portions, each of which was chromatographed on alumina (60 x 2.2 cm). In each case elution with benzene gave orange-red eluates containing a mixture of two major products and one trace component (t.l.c.). Further elution with increasing (to 100%) concentrations of ether in the eluant gave homogeneous yellow eluates. These yellow eluates from the two columns were combined, and after the solvent had been evaporated, the residual solid was dissolved in benzene and purified by passing it through a short column of alumina. The material obtained on evaporation of these eluates was crystallised from cyclohexane, yielding 3,4-dimethyl-1-oxa-6-thia-6aλ^4-selena-2-azapentalene (6) (780 mg, 8.9%) as rusty-red prisms, m.p. 117-118.5°C.

Found: C, 32.7; H 3.2; N, 6.4%.

C_6H_7NOSSe requires: C, 32.7; H, 3.2; N, 6.4%.

Accurate mass determination 220.9418

C_6H_7NOSSe requires 220.9414

^{1}H nmr, ($CDCl_3$): δ 2.96 (3H, d, $J_{4\text{-Me},5}$=0.8 Hz, 4-Me), 3.00 (3H, s, 3-Me), 9.46 (1H, q, 5-H)

uv spectrum, (cyclohexane): λ_{max} (nm) 432 (logε 3.89), 237 (4.25), 203 (4.11)

The residues from the orange-red eluates of the first two columns were separately chromatographed on silica gel (150 x 3 cm) using petrol as eluant. In each case the initial red (t.l.c. pure) eluates were followed by eluates containing the red product and a yellow one (t.l.c.). These were followed by pure (t.l.c.) yellow eluates. The two pure red fractions from the two columns were combined, as were the two pure yellow fractions from the two columns. The two fractions (from the two columns) which contained both the red and the yellow product were combined and rechromatographed in the same way. The result was virtually complete separation of the red and yellow products. The red and yellow fractions from this last column were combined with previous red and yellow fractions, respectively. After evaporation of solvent, each product was crystallised separately from n-hexane. The first product was 3,4-dimethyl-1-thia-6,6aλ^4-diselena-2-azapentalene (4) (1.369 g, 12.1 %) which appeared as red needles, m.p. = 103-105°C.

Found: C 25.6: H, 2.5; N, 5.2%

$C_6H_7NSSe_2$ requires: C, 25.5; H, 2.5; N, 5.0%

Accurate mass determination 284.8616

$C_6H_7NSSe_2$ requires 284.8630

^{1}H nmr, ($CDCl_3$): δ 2.77 (3H, d, $J_{4\text{-Me},5}$=0.8 Hz, 4-Me), 2.86 (3H, s, 3-Me), 10.33 (1H, q, 5-H)

uv spectrum, (cyclohexane): λ_{max} (nm) 468 (log ϵ 3.79), 260 (4.52), 236 (4.37), 213 (4.47)

The second product was 3,4-dimethyl-1,6-dithia-6aλ^4-selena-2-azapentalene (5) (134 mg, 1.4%) which appeared as long orange

needles, m.p. = 84-86.5°C.

Found: C, 30.4; H, 3.0; N, 5.8%

$C_6H_7NS_2Se$ requires: C, 30.5; H, 3.0; N, 5.9%

Accurate mass determination 236.9194

$C_6H_7NS_2Se$ requires 236.9185

^1H nmr, ($CDCl_3$): δ 2.73 (3H, d, $J_{4\text{-Me},5}$=0.8 Hz, 4-Me), 2.91 (3H, s, 3-Me), 9.43 (1H, s, 5-H)

uv spectrum, (cyclohexane): λ_{max} (nm) 440 (log ϵ 3.85), 247 (4.40), 226 (4.41), 212 (4.43)

Trial thionations of 3,4-dimethyl-1-oxa-6,6aλ^4-diselena-2-azapentalene were initially carried out under the following varied conditions, none of which offered yields improved over those available from the conditions used above.

(1) 1 mmol P_2S_5: 1 mmol substrate; solvent, dry benzene, P_2S_5 purified.

(2) 2 mmol P_2S_5: 1 mmol substrate; second half of P_2S_5 added after 15 min; solvent, dry benzene; P_2S_5 purified.

(3) 1 mmol P_2S_5: 1 mmol substrate; solvent, dry benzene; P_2S_5 not purified.

(4) 2 mmol P_2S_5: 1 mmol substrate; solvent, dry benzene/dry carbon disulphide 1:1; P_2S_5 purified.

(5) 2 mmol P_2S_5: 1 mmol substrate; solvent, Analar grade pyridine @ 80°C; P_2S_5 purified.

In order to determine whether the dithiaselena-azapentalene (5) could be formed in the reaction mixture by thionation of the

oxathiaselena-azapentalene (6) or the thiadiselena-azapentalene (4) trial thionations of pure samples of these last two compounds were carried out. Purified phosphorus pentasulphide (444 mg, 2 mmol) was added to a solution of 3,4-dimethyl-1-oxa-6-thia-6aλ^4-selena-2-azapentalene (6) (220 mg, 1 mmol) in dry benzene (15 ml). The reaction was refluxed on an oil bath for 30 min., cooled, and poured into water (50 ml). This mixture was filtered by suction and extracted with benzene (5 x 25 ml). The combined extracts were washed with water, dried, evaporated to low volume, and chromatographed on alumina (40 x 1.5 cm) with benzene as eluant. The initial yellow eluates afforded a trace of product identified by accurate mass determination as 3,4-dimethyl-1,6-dithia-6aλ^4-selena-2-azapentalene (5).

Accurate mass determination 236.9194

$C_6H_7NS_2Se$ requires 236.9185

Later eluates afforded unreacted starting material (84%).

Purified phosphorus pentasulphide (444 mg, 2 mmol) was added to a solution of 3,4-dimethyl-1-thia-6,6aλ^4-diselena-2-azapentalene (4) (283 mg, 1 mmol) in dry benzene (15 ml). The reaction was refluxed in an oil bath for 30 min, cooled, and poured into water (50 ml). The mixture was then filtered by suction and extracted into benzene (4 x 25 ml). The combined extracts were washed with water (3 x 25 ml), dried, and evaporated to low volume. T.l.c. showed no trace of the expected product, 3,4-dimethyl-1,6-dithia-6aλ^4-selena-2-azapentalene (5). A large quantity of starting material was recovered unreacted (92%).

(c) Preparation of 4,5-Dihydro-3H-benzo[cd]-1-oxa-6,6aλ^4-dithia-2-azapentalene

The procedure for the preparation of this compound was largely that of Reid et al.[20]. To a solution of 4,5,6,7-tetrahydrobenzo[c][1,2]dithiolium perchlorate (7) (6.418 g, 24 mmol) in acetic acid/acetonitrile (1:1, 600 ml) was added sodium nitrite (3.449 g, 50 mmol) with stirring. Stirring was continued for 20 min., at room temperature. A second reaction was carried out simultaneously using the dithiolium perchlorate (7) (6.419 g, 25 mmol) and sodium nitrite (3.451 g, 50 mmol) and the same conditions. At the end of the 20 min. period both reactions were poured into the same 3 l of water and this mixture was split into two portions, each of which was extracted with benzene (4 x 600 ml). The combined extracts were washed with water (3 x 500 ml) and dried. The material remaining upon evaporation of the solvent was dissolved in benzene and chromatographed on alumina (20 x 2.7 cm). The benzene was evaporated, and crystallisation of the resulting solid from cyclohexane gave 4,5-dihydro-3H-benzo[cd]-1-oxa-6,6aλ^4-dithia-2-azapentalene (8) (8.197 g, 88%).

(d) Thionation of 4,5-dihydro-3H-benzo[cd]-1-oxa-6,6aλ^4-dithia-2-azapentalene

To a stirring solution of 4,5-dihydro-3H-benzo[cd]-1-oxa-6,6aλ^4-dithia-2-azapentalene (8) (3.706 g, 20 mmol) in dry benzene (300 ml) was added phosphorus pentasulphide (8.890 g, 40 mmol) and the mixture was refluxed on an oil bath for 45 min. .

A second reaction was carried out simultaneously using the oxadithia-azapentalene (8) (3.704 g, 20 mmol) and phosphorus pentasulphide (8.890 g, 40 mmol) and the same conditions. After a few minutes cooling, both reactions were poured into the same 1 l of water, filtering through a glass-wool plug. The water was extracted with benzene (2 x 300 ml + 3 x 200 ml), and the solid which had been filtered off was thoroughly washed with the benzene used for these extractions. After drying, the extracts were evaporated to low volume and chromatographed on a column of silica gel (50 x 2.8 cm) with benzene as eluant. The first, dark red eluates from this column were evaporated, and the solid redissolved in petrol/benzene (2:1) and rechromatographed on silica gel (50 x 2.2 cm). The red eluates from this column gave a solid which was crystallised from n-hexane to give dark red needles m.p. = 93-94.5°C.

This proved not to be the expected trithia-azapentalene (9) but rather a product tentatively identified as 7-oxo-4,5,6,7-tetrahydro-benzo[d]-1,2-dithiole-3-thione (10a) (138 mg, 2%) or its isomer (10b).

Found: C 41.7; H, 2.9; O, 8.1; S, 47.8%

$C_7H_6OS_3$ requires: C, 41.6; H, 3.0; O, 7.9; S, 47.6%

Accurate mass determination 201.9706

$C_7H_6OS_3$ requires 201.9581

^{1}H nmr, ($CDCl_3$): δ 2.21 (2H, quintet, 5-H_2), 2.64-2.86 (4H, m, 4-H_2 and 6-H_2)

uv spectrum, (cyclohexane): λ_{max} (nm) 488sh (log ϵ 3.73), 470 (3.86), 289 (3.82), 260 (3.88), 240 (4.15)

Further elution of the initial column gave an intermediate fraction which was discarded, followed by a final fraction eluted with increasing concentrations of ether in the benzene. The material in this final fraction was purified by passing through a short column of alumina (8 x 2.2 cm) with benzene, providing a small recovery of starting material (8) (514 mg, 7%) identified by t.l.c. and m.p. (m.p. found = 95-96°C, lit.[20] 95-96°C).

2. 6-Methyl-1-oxa-6aλ^4-thia-2,6-diazapentalene and Related Compounds

(a) Preparation of Isothiazole-5-carboxaldoxime

To a solution of redistilled 5-formylisothiazole (16) (b.p. =74°/15 mm Hg) (11.314 g, 100 mmol) in methanol (65 ml) was added a solution of hydroxyammonium chloride (8.340 g, 120 mmol) and sodium carbonate (7.420 g, 70 mmol) in water (30 ml). The reaction was refluxed in an oil bath for 30 min., cooled to room temperature, and neutralised by dropwise addition of acetic acid. Then water (375 ml) was added and the resulting slurry was extracted with ether (4 x 150 ml). The extracts were dried and evaporated, and the crude product (Z:E = 7:1) was crystallised from benzene to give isothiazole-5-carboxaldoxime (17) (11.22 g, 88%) as white powdery crystals, m.p. = 127-128°C, considerably enriched in the Z isomer.

Found: C, 37.5; H, 3.1; N, 21.7%

$C_4H_4N_2OS$ requires: C, 37.5; H, 3.2; N, 21.9%

^{1}H nmr, (dmso-D_6): (Z isomer) δ 7.63 (1H, dd, $J_{3,4}$=1.9 Hz), $J_{4,1'}$=0.4Hz, 4-H), 8.13 (1H, bs, 1'-H), 8.53 (1H, d, 3-H), 12.87 (1H, bs, OH).

uv spectrum, (methanol): λ_{max} (nm) 265 (log ϵ 4.02)

(1% $HClO_4$ in methanol): λ_{max} (nm) 265 (log ϵ 4.00)

(b) Synthesis of 5-Hydroxyiminomethyl-2-methylisothiazolium Tosylate and 5-(N-Methyl-N-hydroxyiminomethyl)isothiazole Tosylate

To a solution of methyl toluene-p-sulphonate (methyl tosylate)

(14.898 g, 80 mmol) in dry benzene (25 ml) was added isothiazole-5-carboxaldoxime (17) (10.253 g, 80 mmol) with dry benzene (15 ml). The reaction mixture was refluxed for 1 h., and allowed to cool to room temperature and settle for 2.5 h. A viscous amber-coloured oil formed a layer on the bottom of the flask. Ether (50 ml) was added and the mixture was left undisturbed for 20 min., after which time the solvent was decanted off and the oil was washed twice with portions of ether (50 ml). The oil was then dissolved in acetone (20 ml) and allowed to stand overnight, during which time some ether (5 ml) was added. The crystals were filtered off and washed with acetone/ether (1:9) (2 x 20 ml) and ether (3 x 20 ml). They were then recrystallised from ethanol, giving a mixture of the two isomeric products (18) and (20) (4.679 g, 14.9 mmol, 18.6%). From this mixture 4.7 mmol was used for preliminary deprotonation and separation experiments. Samples of the pure isomers were obtained from 10 mmol of this mixture by fractional crystallisation from acetonitrile. The first crop was 5-hydroxyiminomethyl-2-methylisothiazolium tosylate (18) (1.541 g, 6.1%) as light brown prisms, m.p. = 160.5-169°C dec. . (The overall yield of this product based on 14.9 mmol of mixture is then, by extrapolation, 9.1%).

Found: C, 45.9; H, 4.5; N, 8.9%

$C_{12}H_{14}N_2O_4S_2$ requires: C, 45.8; H, 4.5; N, 8.9%

^{1}H nmr, (dmso-D_6): δ 2.29 (3H, s, $ArCH_3$), 4.10 (3H, d, $J_{3,NMe}$=0.7 Hz, N-Me), 7.10 and 7.18 (2H, d, 2-H and 6-H of tosylate anion), 7.50 and 7.58 (2H, d, 3-H and 5-H of tosylate anion),

7.88 (1H, d, $J_{3,4}$=3.1 Hz, $J_{1',4}$=0.5Hz, 4-H), 8.97 (1H, s 1'-H), 9.09 (1H, dq, 3-H), 10.34 (1H, s, OH)

uv spectrum, (methanol): λ_{max} (nm) 334 (log ϵ 3.89), 253 pl (3.25), 218 (4.24)

(1% $HClO_4$ in methanol): λ_{max} (nm) 331 sh (log ϵ 3.47), 302 (3.96), 265 sh (3.56), 219 (4.15), 210 sh (4.02)

The second crop of crystals from acetonitrile consisted of 5-(N-methyl-N-hydroxyiminomethyl)isothiazole tosylate (20) (0.808 g, 3.2%), off-white prisms, m.p. = 139.5-144.5°C. A portion of this material was recrystallised from acetonitrile for analysis. (The overall yield of this product based on 14.9 mmol of mixture is then, by extrapolation, 4.8%)

Found: C 45.8; H, 4.4; N, 9.0%

$C_{12}H_{14}N_2O_4S_2$ requires: C, 45.8; H, 4.5: N, 8.9%

^{1}H nmr, (dmso-D_6): δ 2.30 (3H, s, $ArCH_3$), 3.94 (3H, d, $J_{1',NMe}$=0.7 Hz, NMe), 7.14 and 7.22 (2H, d, 2-H and 6-H of tosylate anion), 7.55 and 7.63 (2H, d, 3-H and 5-H of tosylate anion), 7.77 (1H, bd, $J_{3,4}$ =2.0Hz, $J_{1',4}$=0.4Hz, 4-H), 8.60 (1H, d, 3-H), 8.81 (1H, m, 1'-H), 10.18 (1H, bs, OH)

uv spectrum, (methanol): λ_{max} (nm) 310 sh (log ϵ 4.05), 300 (4.11), 226 sh (3.96), 216 (4.19)

(1% $HClO_4$ in methanol): λ_{max} (nm) 327 sh (log ϵ 3.93), 317 (3.97), 250 pl (3.31), 227 sh (3.96), 217 (4.22)

(c) Synthesis of 6-Methyl-1-oxa-6aλ^4-thia-2,6-diazapentalene

To a solution of 5-hydroxyiminomethyl-2-methylisothiazolium tosylate (18) (1.572 g, 5 mmol) in water (25 ml) was added a solution of sodium carbonate (0.530 g, 5 mmol) in water (15 ml). After 15 min. the reaction mixture was extracted with methylene chloride (4 x 60 ml). The extracts were dried and evaporated. The resulting yellow crystals were sublimed under vacuum (ca. 130°C/ca. 0.1 mm Hg). The yield of sublimed product was 683 mg (97%). This material was crystallised from benzene to give 6-methyl-1-oxa-6aλ^4-thia-2,6-diazapentalene (19) (615 mg, 87%) as yellow plates, m.p. = 91.5-92°C.

Found: C, 42.4; H, 4.3; N, 19.8%

$C_5H_6N_2OS$ requires: C, 42.2; H, 4.3; N, 19.7%

Accurate mass determination 142.0191

$C_5H_6N_2OS$ requires 142.0201

^{1}H nmr, (dmso-D_6): δ 3.74 (3H, d, $J_{5,NMe}$=0.7Hz, NMe), 7.43 (1H, d, $J_{4,5}$=3.6Hz, 4-H), 8.61 (1H, dq, 5-H), 9.08 (1H, s, 3-H)

($CDCl_3$): δ 3.72 (3H, d, $J_{5,NMe}$=0.7Hz, NMe), 7.20 (1H, d, $J_{4,5}$=3.6Hz, 4-H), 8.15 (1H, dq, 5-H), 8.92 (1H, s, 3-H)

(CF_3COOH): protonates at oxygen, numbering as for a substituted isothiazole structure. δ 4.40 (3H, d, $J_{3,NMe}$= 0.6Hz, NMe), 8.08 (1H, d, $J_{3,4}$=3.1Hz, 4-H), 8.92 (1H, s, overlaps 3-H, 1'-H), 8.95 (1H, dq, overlaps 1'-H, 3-H)

(5% $HClO_4$ in CF_3COOH): nmr same as in CF_3COOH

uv spectrum, (methanol): λ_{max} (nm) 334 (log ϵ 4.00), 243 pl (3.10), 216 (4.03)

(1% $HClO_4$ in methanol): λ_{max} (nm) 331 sh (log ϵ 3.34), 301 (3.97), 265 sh (3.56), 216 sh (3.58), 2.04 (3.63)

(d) Synthesis of 5-Hydroxyiminomethyl-2-methylisothiazolium Perchlorate

To a solution of 6-methyl-1-oxa-6a λ^4-thia-2,6-diazapentalene (19) (142 mg, 1 mmol) in filtered methanol (4 ml) was added perchloric acid (277 mg as 72% aq., 2 mmol), with swirling. After 15 min., ether (25 ml) was added and the resulting precipitate was filtered off and dried. 5-Hydroxyiminomethyl-2-methylisothiazolium perchlorate (21) (225 mg, 93%) was obtained as white powdery needles, m.p. = 113-122.5°C dec.

Found: C, 24.7; H, 3.0; N, 11.8%

$C_5H_7N_2O_5SCl$ requires: C, 24.8; H, 2.9; N, 11.6%

^1H nmr, (dmso-D_6): δ 4.10 (3H, d, $J_{3,NMe}$=0.7Hz, NMe), 7.85 (1H, bd, $J_{3,4}$=3.1Hz, $J_{1',4}$=0.4Hz, 4-H), 8.91 (1H, s, 1'-H), 9.05 (1H, dq, 3-H), 10.84 (1H, bs, OH)

uv spectrum, (methanol): λ_{max} (nm) 334 (log ϵ 3.93), 249 pl (3.15), 216 (3.94)

(1% $HClO_4$ in methanol): λ_{max} (nm) 332 (log ϵ 3.45), 301 (3.96), 265 sh (3.53), 214 sh (3.52)

(e) Synthesis of C-(5-Isothiazolyl)-N-methylnitrone by Deprotonation of 5-(N-methyl-N-hydroxyiminomethyl)-isothiazole Tosylate

To a solution of 5-(N-methyl-N-hydroxyiminomethyl)isothiazole tosylate (20) (314 mg, 1 mmol) in water (5 ml) was added a solution of sodium carbonate (106 mg, 1 mmol) in water (5 ml). After 15 min. the solution was extracted with methylene chloride (4 x 10 ml). The extracts were dried and evaporated, giving C-(5-isothiazolyl)-N-methylnitrone (22) (134 mg, 94%) whose ^1H nmr spectrum was identical to that of a known sample of the nitrone (22) prepared by a different route. (see f below)

(f) Synthesis of C-(5-Isothiazolyl)-N-methylnitrone from 5-Formyl-isothiazole

To a solution of 5-formylisothiazole (16) (1.130 g, 10 mmol) in methanol (6.5 ml) was added a solution of N-methylhydroxylamine (1.002 g, 12 mmol) and sodium carbonate (1.271 g, 12 mmol in water (12 ml). The reaction was refluxed for 30 min. in an oil bath, then allowed to cool before the addition of water (20 ml) and extraction with methylene chloride (4 x 50 ml). The extracts were dried and evaporated leaving C-(5-isothiazolyl)-N-methylnitrone (22) (1.386 g, 98%). Recrystallisation from benzene gave the product as white needles m.p. = 143.5-144°C.

Found: C, 42.4; H, 4.1; N, 19.8%

$C_5H_6N_2OS$ requires: C, 42.2; H, 4.3; N, 19.7%

Accurate mass determination 142.0194

$C_5H_6N_2OS$ requires 142.0201

^{1}H nmr, (dmso-D_6): δ 3.94 (3H, d, $J_{1',NMe}$=0.8Hz, NMe), 7.76 (1H, bd, $J_{1',4}$=0.5Hz, $J_{3,4}$=2.0Hz, 4-H), 8.58 (1H, d, 3-H), 8.75 (1H, m, 1'-H)

($CDCl_3$): δ 3.98 (3H, d, $J_{1',NMe}$=0.8Hz, NMe), 7.51 (1H, bd, $J_{3,4}$=2.0Hz, 4-H), 8.17 (1H, bs, 1'-H), 8.52 (1H, bd, 3-H)

(CF_3COOH): δ 4.28 (3H, s on 1000 Hz scale, NMe), 8.10 (1H, bd, $J_{3,4}$=3.1Hz, 4-H), 8.97 (1H, d, 3-H), 9.04 (1H, m, 1'-H)

no proton exchange observed in CF_3COOD

uv spectrum, (methanol): λ_{max} (nm) 310 sh (log ϵ 4.05), 300 (4.10), 247 pl (3.35), 212 (3.80)

(1% $HClO_4$ in methanol): λ_{max} (nm) 326 sh (log ϵ 3.91), 316 (3.95), 247 pl (3.32), 213 (3.84)

(g) Synthesis of 5-(N-Methyl-N-hydroxyiminomethyl)isothiazole Perchlorate

To a solution of C-(5-isothiazolyl)-N-methylnitrone (22) (711 mg, 5 mmol) in methanol (20 ml) was added perchloric acid (1.397 g as 72% aq, 10 mmol) with swirling. After 15 min. ether (30 ml) was added and the precipitate was filtered off, washed with ether, and dried. The crude yield was almost quantitative. Crystallisation from methanol gave a first crop of 5-(N-methyl-N-hydroxyiminomethyl)isothiazole perchlorate (23) (914 mg, 75%) as colourless prisms, m.p. = 190.5-201.5 .

Found: C, 24.6; H, 3.0; N, 11.7%

$C_5H_7N_2O_5SCl$ requires: C, 24.8; H, 2.9; N, 11.6%

^{1}H nmr, (dmso-D_6): δ 3.95 (3H, d, $J_{1',NMe}$=0.7Hz, NMe), 7.78 (1H, bd, $J_{3,4}$=2.0Hz, $J_{1',4}$=0.5Hz, 4-H), 8.61 (1H, d, 3-H), 8.77 (1H, m, 1'-H)

(CF_3COOH): δ 4.34 (3H, d, $J_{1',NMe}$=0.8Hz, NMe), 8.19 (1H, bd, $J_{3,4}$=3.1Hz, $J_{1',4}$=0.5Hz, 4-H), 9.04 (1H, d, 3-H), 9.10 (1H, m, 1'-H)

uv spectrum, (methanol): λ_{max} (nm) 310 sh (log ϵ 4.10), 300 (4.15), 244 pl (3.12), 212 (3.86)

(1% $HClO_4$ in methanol): λ_{max} (nm) 326 sh (log ϵ 3.99), 317 (4.03), 248 pl (3.08), 213 (3.91)

(h) Synthesis of 5-(N-Methyl-N-oxidoimmoniomethyl)-2-methylisothiazolium Fluorosulphonate

To a solution of C-(5-isothiazolyl)-N-methylnitrone (22) (710 mg, 5 mmol) in methylene chloride (10 ml) was added methyl fluorosulphonate (0.81 ml, 10 mmol). A copious precipitate quickly formed. After 15 min. ether (15 ml) was added and the solid was filtered off and washed with ether. 5-(N-methyl-N-oxidoimmoniomethyl)-2-methylisothiazolium fluorosulphonate (24) (1.22 g, 95%) was obtained as off-white microprisms, m.p. = 151.5-154.5°C.

Found: C, 28.3; H, 3.6; N, 10.9%

$C_6H_9N_2O_4S_2F$ requires: C, 28.1; H, 3.5: N, 10.9%

^{1}H nmr, (dmso-D_6): δ 4.17 (3H, bs, overlaps ring NMe, $J_{1',NMe}$ = 0.7Hz, $=\overset{+}{N}\overset{-}{O}Me$), 4.19 (3H, bs, overlaps $=\overset{+}{N}\overset{-}{O}Me$, $J_{3,2\text{-}Me}$ = 0.6Hz, 2-Me), 8.16 (1H, bd, $J_{3,4}$ = 3.2Hz, 4-H), 9.17 (1H, dq, 3-H), 9.40 (1H, bs, 1'-H)

(CF_3COOH): δ 4.31 (6H, b, 2 x N-Me), 8.06 (1H, bd, $J_{3,4}$ = 3.2Hz, 4-H), 8.85 (1H, dq, $J_{3,2\text{-}Me}$ = 0.7Hz, 3-H), 9.01 (1H, bs, 1'-H)

no proton exchange observed in CF_3COOD

(5% $HClO_4$ in CF_3COOH): δ 4.30 (3H, bs, overlaps 2-Me, $=\overset{+}{N}\overset{-}{O}Me$), 4.32 (3H, bs, overlaps $=\overset{+}{N}\overset{-}{O}Me$, 2-Me), 8.09 (1H, bd, $J_{3,4}$ = 3.0Hz, 4-H), 8.87 (1H, dq, $J_{3,2\text{-}Me}$ = 0.6Hz, 3-H), 9.03 (1H, bs, 1'-H)

uv spectrum, (methanol): λ_{max} (nm) 331 (logϵ 3.96), 260 (3.44), 218 (3.95)

(1% $HClO_4$ in methanol): λ_{max} (nm) 331 (logϵ 3.97), 260 (3.46), 218 (3.94)

(i) Synthesis of 5-Methoxyiminomethylisothiazole

To a solution of 5-formylisothiazole (16) (1.133 g, 10 mmol) in methanol (15 ml) was added a solution of methoxyamine hydrochloride (1.003 g, 12 mmol) and sodium carbonate (1.272 g, 12 mmol) in water (15 ml). The reaction stood at room temperature for 24 h. A second reaction was carried out simultaneously using 5-formylisothiazole (16) (1.133 g, 10 mmol), methoxyamine hydrochloride (1.002 g, 12 mmol), and sodium carbonate (1.272 g,

12 mmol) and the same conditions. The work-up procedure was the same for both reactions. After the end of the 24 h period water (75 ml) was added to the reaction mixture, which was then extracted with ether (4 x 150 ml). The extracts were dried and evaporated. The residue was block distilled (105-110°C/16 mm Hg) giving 5-methoxyiminomethylisothiazole (25) (1.208 g, 85%) as a colourless oil. (an equal mixture of E and Z isomers by ^{1}H nmr) The second reaction which was carried out at the same time gave, by the same procedure, the product (25) (1.211 g, 85%).

Found: C, 42.4; H, 4.3: N, 19.7%

$C_5H_6N_2OS$ requires: C, 42.2; H, 4.3; N, 19.7%

^{1}H nmr, ($CDCl_3$): resonances marked * were determined by spin decoupling to be of the same isomer.

δ 3.97 (3H, s, OMe), 4.16 (3H, s, OMe), 7.26 (1H, dd, $J_{3,4}$=1.8Hz, $J_{1',4}$=0.4Hz, 4-H)*, 7.37 (1H, bd, $J_{3,4}$=1.8Hz, 4-H), 7.82 (1H, s, 1'-H), 8.24 (1H, s, 1'-H)*, 8.44 (1H, d, overlaps other 3-H, 3-H)*, 8.46 (1H, d, overlaps other 3-H*, 3-H)

(dmso-D_6): from unexpanded spectrum

δ 3.94 (3H, s, OMe), 4.12 (3H, s, OMe), 7.61 (1H, d, 4-H), 7.75 (1H, d, 4-H), 8.26 (1H, s, 1'-H), 8.59 (1H, s, 1'-H), 8.62 (2H, m, 2 x 3-H)

uv spectrum, (methanol): λ_{max} (nm) 273 (log ε 4.11)

(1% $HClO_4$ in methanol): λ_{max} (nm) 273 (log ε 4.10)

(j) Synthesis of 5-Methoxyiminomethyl-2-methylisothiazolium Fluorosulphonate

To a solution of 5-methoxyiminomethylisothiazole (25) (711 mg, 5 mmol) in methylene chloride (10 ml) was added methyl fluorosulphonate (0.81 ml, 10 mmol). After 15 min. ether (15 ml) was added and the precipitate was filtered off and washed with ether, giving the product (26) (1.112 g, 87%). This material was recrystallised with difficulty from a small volume of acetonitrile yielding, in three crops, 5-methoxyiminomethyl-2-methylisothiazolium fluorosulphonate (26) (561 mg, 44%) as white needles, m.p. = 167-168°C.

Found: C, 28.2; H, 3.9; N, 11.1%

$C_6H_9N_2O_4S_2F$ requires: C, 28.1; H, 3.5; N, 10.9%

^1H nmr, (dmso-D_6): δ 4.32 (3H, s, OMe), 4.36 (3H, d, $J_{3,NMe}$=0.7 Hz, NMe), 8.13 (1H, bd, $J_{1',4}$=0.5Hz, $J_{3,4}$=2.9Hz, 4-H), 8.78 (1H, s, 1'-H), 9.42 (1H, dq, 3-H)

uv spectrum, (methanol): λ_{max} (nm) 307 sh (log ϵ 4.06), 300 (4.08), 264 sh (3.59), 205 (3.73)

(1% $HClO_4$ in methanol): λ_{max} (nm) 307 sh (log ϵ 4.06), 300 (4.08), 262 sh (3.57), 206 (3.70)

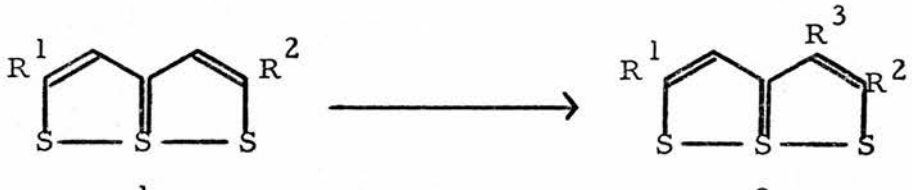
PART II

REACTIONS OF 1,6,6aλ^4-TRITHIAPENTALENES WITH ARENEDIAZONIUM TETRAFLUOROBORATES

DISCUSSION OF BACKGROUND LITERATURE

1. 1, 6, 6a λ^4-Trithiapentalenes: Susceptibility of C-3(4) and S-1(6) to Electrophilic Attack

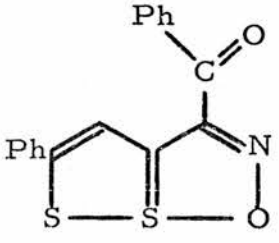
The reactions of 1, 6, 6a λ^4-trithiapentalenes with electrophiles have been the subject of several recent studies. Beer and his co-workers[92] reported that bromination of the trithiapentalenes (1a) and (1b) occurred at the 3-position to yield the simple bromo



1 2

a. $R^1=R^2=Ph$
b. $R^1=R^2=Me$
c. $R^1=Ph, R^2=SMe$

derivatives [(2a) and (2b), $R^3=Br$]. Bromination and nitration of 2-methylthio-5-phenyl-1, 6, 6a λ^4-trithiapentalene (1c) gave the 3-bromo compound (2c, $R^3=Br$) and the 3-nitro compound (2c, $R^3=NO_2$), respectively. Nitrosation and nitration of 2, 5-diphenyl-1, 6, 6a λ^4-trithiapentalene (1a), however, gave product (3) alone by



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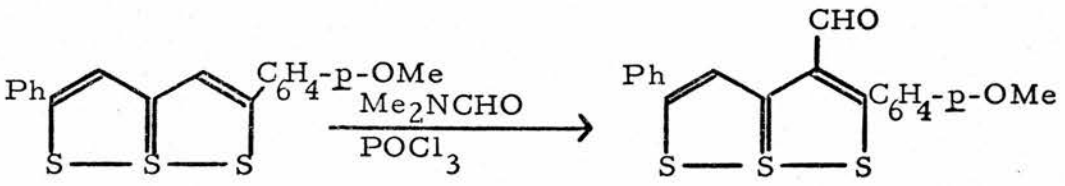
electrophilic attack at C-3, rearrangement, and hydrolysis of the

resulting thiocarbonyl group.

Bignebat and Quiniou[94] have reported that the 2,5-disubstituted



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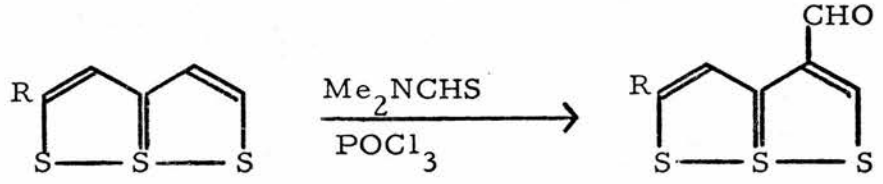
trithiapentalene (4) reacts with $POCl_3$/dimethylformamide to give the 3-formylated product (5).

The definitive work of Reid et al.[94] has shown that the

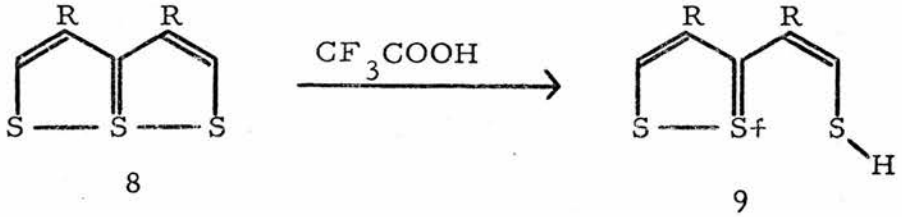


6 7

R = H, Bu^t, Ph

1,6,6aλ^4-trithiapentalenes (6) are formylated exclusively at C-3(4) with NN-dimethylthioformamide-phosphoryl chloride to give the aldehydes (7).

The 3,4-disubstituted trithiapentalenes (8) are protonated at sulphur in trifluoroacetic acid to yield the dithiolium species (9)[57].



8 9

R=Me

or -R-R- = $-(CH_2)_2-$, $-(CH_2)_3-$

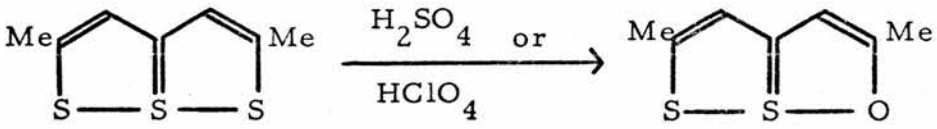
Trithiapentalenes (10) with an electron-releasing substituent in the

2-position are protonated at C-3 in trifluoroacetic acid to give

10 R=SMe, NMe_2 11

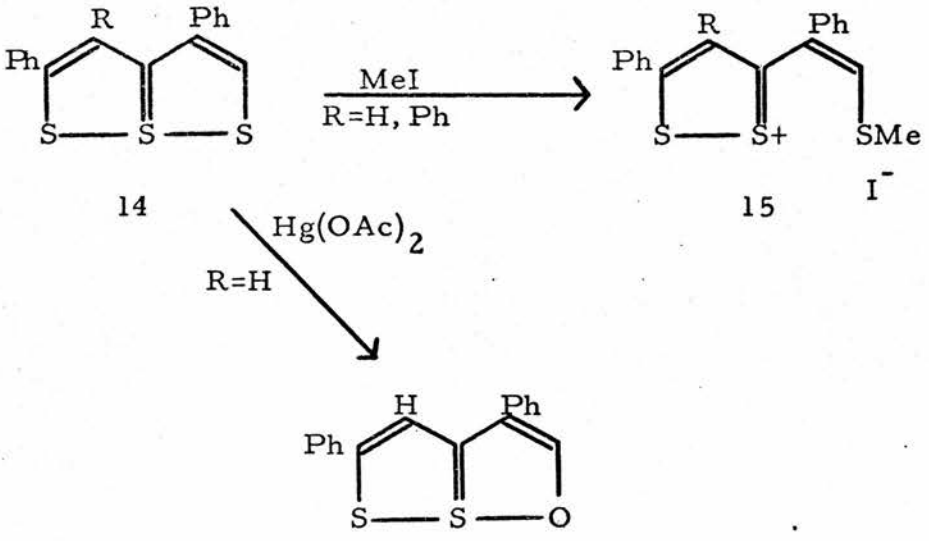
the species (11)[57]. Experiments in the same study[57] show that various trithiapentalenes undergo hydrogen/deuterium exchange at C-3(4) in deuteriotrifluoroacetic acid.

Among the reactions reported which involve electrophilic attack at sulphur in trithiapentalenes are the following. 2,5-Dimethyl-1,6,6aλ^4-trithiapentalene (12) forms the 1-oxa analogue (13) on



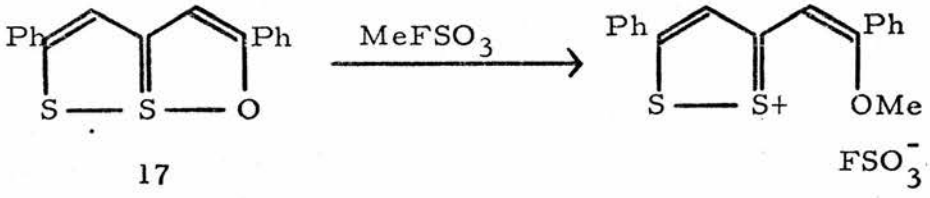
12 13

treatment with 70% perchloric acid or 96% sulphuric acid[43]. The trithiapentalenes (14, R=H, Ph) undergo methylation at sulphur with methyl iodide[47] to give the salts (15), and compound (14, R=H) forms the oxadithiapentalene (16) when allowed to react with mercuric acetate[30,47]. 1-Oxa-6,6aλ^4-dithiapentalenes [e.g. (17)] are



14 15 16

methylated at oxygen, but require the stronger methylating agent



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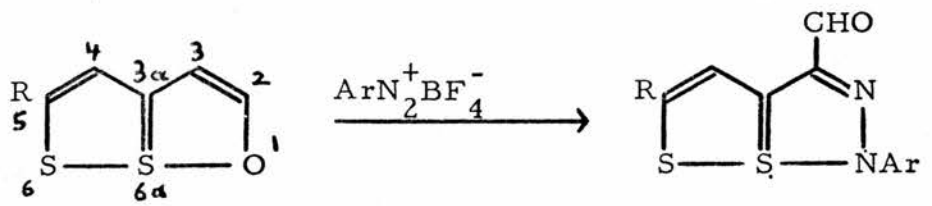
methyl fluorosulphonate[95].

A more comprehensive survey of these reactions is available[96].

2. Reactions of 1-Oxa-6, 6a λ^4-dithiapentalenes with Arenediazonium Tetrafluoroborates

Oxadithiapentalenes (18) unsubstituted at position 3 react rapidly at position 3 with arenediazonium tetrafluoroborates, in acetonitrile, with rearrangement to give 3-formyldithiadiazapentalenes

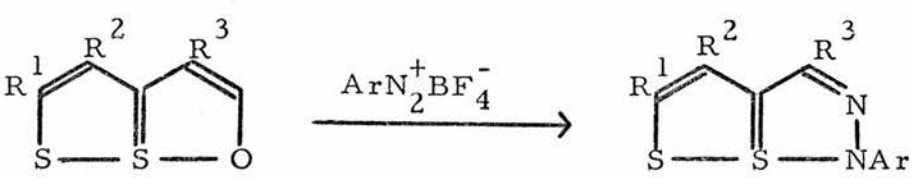


18 19

20 21

(19) in high yield[56]. The unrearranged structure (20) is not observed, and the product is postulated to arise from an intermediate of the form (21) by deprotonation.

Oxadithiapentalenes (22) which are blocked at position 3 by alkyl substituents react with arenediazonium tetrafluoroborates



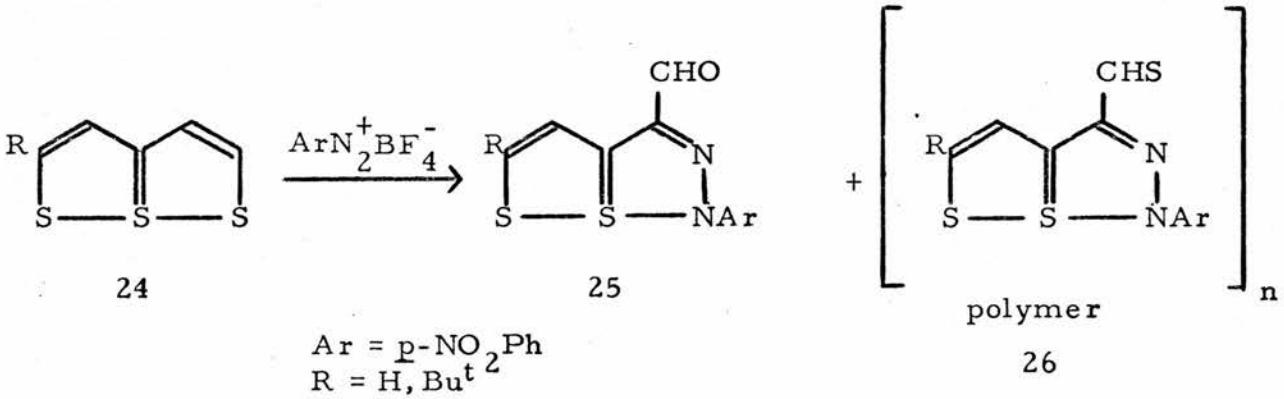
22 23

with deformylation to form dithiadiazapentalenes (23) in high yield[56].

Traces of water in the acetonitrile solution are thought to assist the expulsion of the formyl group. There is no evidence for attack at oxygen, and diazo-coupling at position 4, also not observed, would involve a 1,2-oxathiolium intermediate presumed to be of relatively high energy.

3. Reactions of 2-Substituted 1, 6, 6a λ^4-Trithiapentalenes with Arenediazonium Tetrafluoroborates

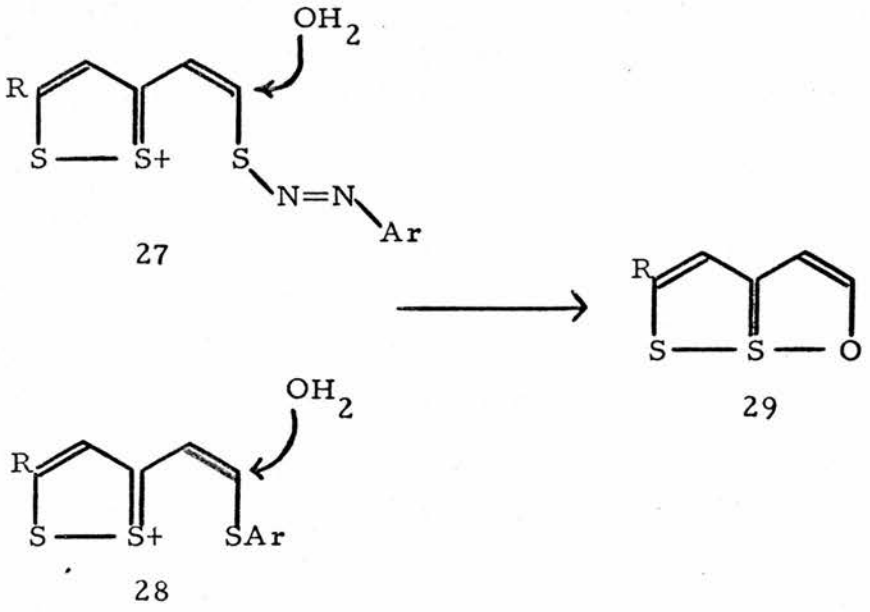
The reaction of trithiapentalenes (24), which are unsubstituted at position 4, with p-nitrobenzenediazonium tetrafluoroborate in acetonitrile gives two products, (25) and (26) in low yield[54]. This



24 25 polymer 26

Ar = p-NO_2Ph
R = H, Bu^t

result can be accommodated by assuming that initial diazo-coupling occurs at position 4 and subsequent rearrangement gives the more stable 6, 6a λ^4-dithia-1, 2-diazapentalene structure. Some of the resulting thioaldehyde may then be hydrolysed to the aldehyde (25) and the remainder polymerises (26). A suggested alternative route to the aldehyde involves the formation of an intermediate of the type (27) or (28) and its hydrolysis by traces of water to the oxadithiapentalene (29), which would then react rapidly with excess of arenediazonium ion to give the aldehyde (25)[54].

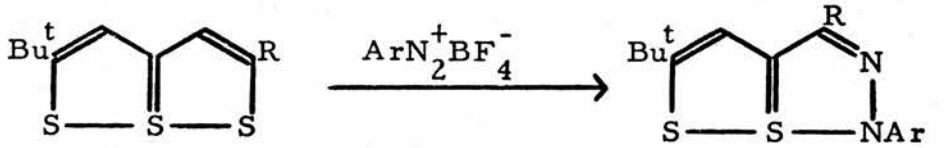


27

29

28

Given this result, it was considered desirable to carry out the same reaction on 2, 5-disubstituted trithiapentalenes each having one 5-substituent (t-butyl) which would hinder attack at its ortho carbon site, and one 2-substituent which would stabilise the proposed thiocarbonyl intermediate[54]. The thiocarbonyl-stabilising groups chosen were the methylthio and dimethylamino groups. They also activate position 3 to electrophilic attack. 2-Methylthio-5-t-butyl-1, 6, 6aλ^4-trithiapentalene (30a) reacted with p-nitrobenzenediazonium tetrafluoroborate to give the dithiadiazapentalene (31a). The resulting dithioester group is sufficiently stable not to be hydrolysed or to polymerise. Similarly, the 2-dimethylamino-trithiapentalene (30b) gave the stable NN-dimethylthiocarboxamide (31b) and a small amount of the amide (31c). This amide may have arisen by hydrolysis of an intermediate (32) formed by attack of diazonium ion on the thioamide (31b).



30

a. R = SMe

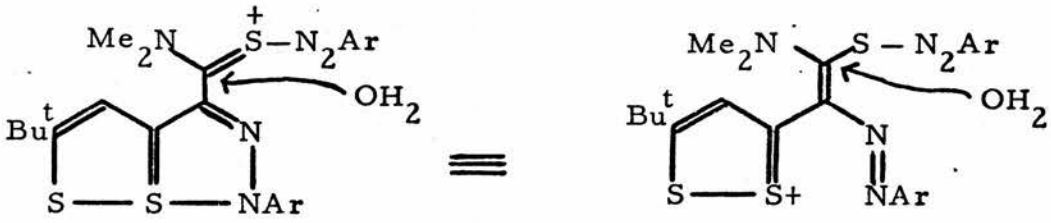
b. R = NMe_2

31

a. R = CS_2Me

b. R = $CSNMe_2$

c. R = $CONMe_2$



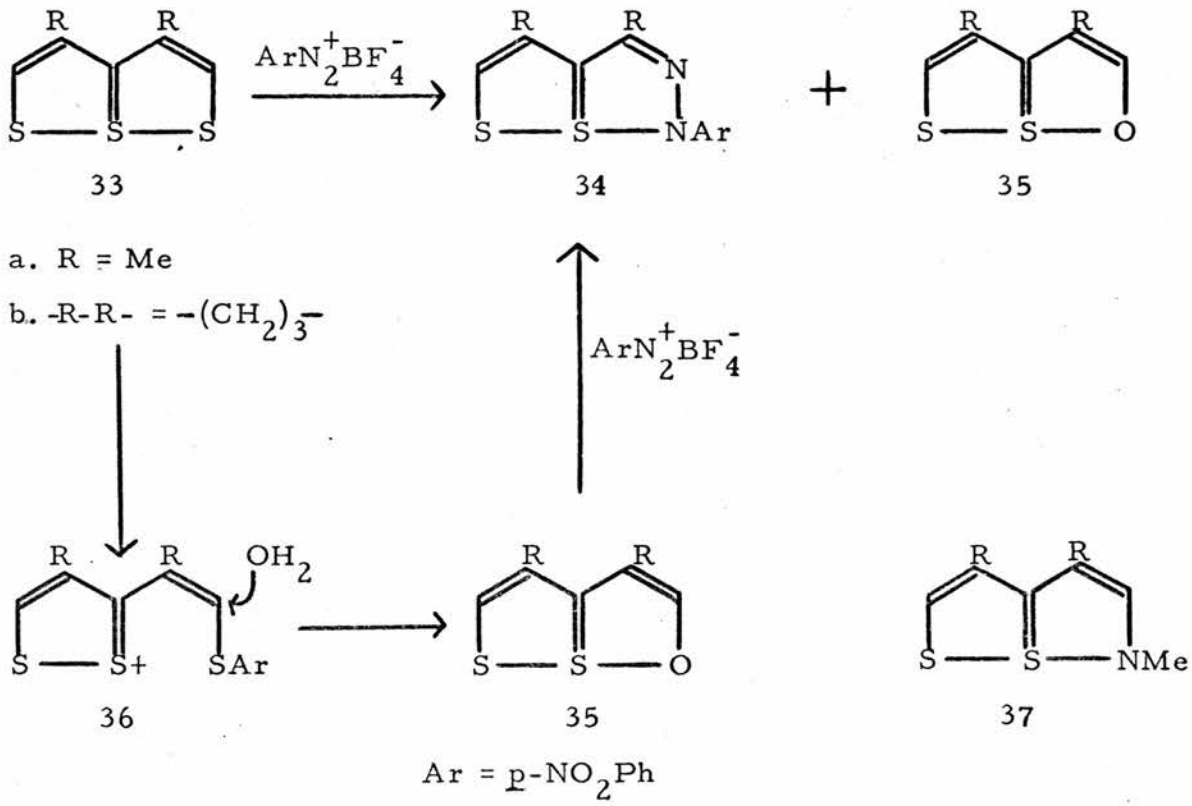
32a

32b

Ar = p-NO_2Ph

4. Reactions of 3,4-Disubstituted 1,6,6aλ^4-Trithiapentalenes with Arenediazonium Tetrafluoroborates

Trithiapentalenes (33) blocked by alkyl substituents at positions 3 and 4 react with p-nitrobenzenediazonium tetrafluoroborate



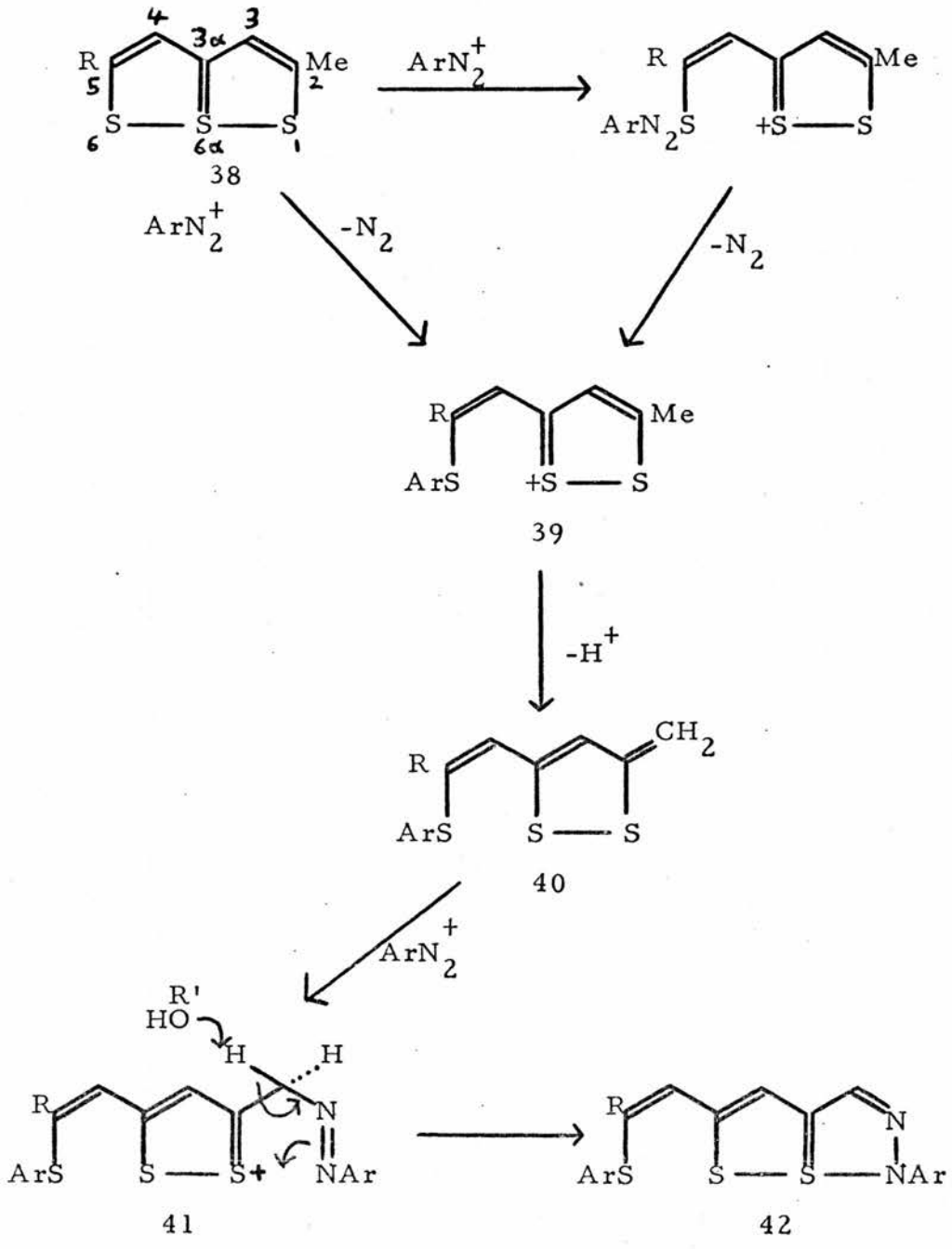
in acetonitrile giving low yields of the expected dithiadiazapentalenes (34) and small amounts of the respective oxadithiapentalenes (35)[54]. These latter may result from hydrolysis by traces of water of an intermediate of the form (36). The oxadithiapentalenes (35) which would result are known[54] (see section 2. above) to react smoothly with p-nitrobenzenediazonium tetrafluoroborate with concomitant deformylation to give the dithiadiazapentalenes (34). Direct attack of the p-nitrobenzenediazonium cation at position 3(4) of (33) requires

subsequent dethioformylation, which is readily possible, to give (34), but cannot easily explain the presence of the oxadithiapentalene (35).

In an attempt to clarify the mechanism, this reaction was later carried out in methanol, using the same substrates and reagent[96]. After extraction with benzene, starting material (33) and product (34) were isolated, but the oxadithiapentalenes (35) were not. Treatment of the remaining aqueous layers with methylamine yielded, on workup, further small quantities of starting material (33) and another product, the dithia-azapentalene (37). This means that a relatively significant amount of reacted substrate is water-soluble and suggests its existence in an ionic form, possibly (36). Formation of dithia-azapentalene from dithiolium salts by reaction with primary amines has been observed[57], but only highly aryl-substituted derivatives give substantial yields.

5. Reactions of 2-Methyl(ene)-1, 6, 6a λ^4-trithiapentalenes with Arenediazonium Tetrafluoroborates

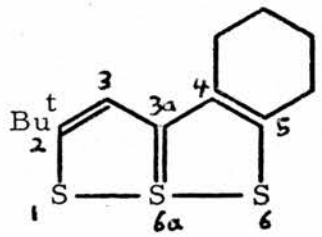
It has been suggested[54, 96] that electrophilic substitution reactions of trithiapentalenes [e.g. (38)] with arenediazonium cations may involve attack at S-1(6) with the formation of a



dithiolium ion intermediate [e.g. (39)]. A methyl(ene) group

position 2 (of the substrate) would then be activated to solvent-assisted deprotonation. (It is well established that the protons of a 3-methyl(ene) group of 1,2-dithiolium salts are acidic[40].) Such deprotonation would result in a neutral species (40) in which the methylene(methenyl) carbon(s) would be highly susceptible to attack by a second arenediazonium ion. Attack of this type could lead to an intermediate of the form (41) and subsequently to a product (42) in which the arylthio intermediate (39) had been trapped. Such a compound (42) might be isolable and would provide additional evidence for a mechanism involving attack at sulphur. Elimination of nitrogen, during or after the initial attack, resulting in the species (39) would not be unexpected, and some possible mechanisms for this have been suggested[96].

With this in mind, compound (43) was treated in methanol solution with p-nitrobenzenediazonium tetrafluoroborate and was found to provide the expected product (44a) in moderate yield[96]. (percent yield figures accompany the diagrams.) The absence of the next most likely product (45) may be due, in part, to the weak inductive activating effect of the 2-t-butyl group which makes S-1 more susceptible to electrophilic attack than S-6. The same reaction using benzenediazonium tetrafluoroborate resulted in virtually quantitative recovery of substrate and only 0.5% of a compound tentatively identified by its mass spectrum as (44b) [accurate mass = 450.1266, $C_{25}H_{26}S_3N_2$ requires 450.1258].



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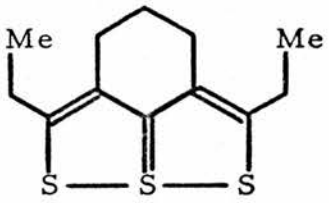

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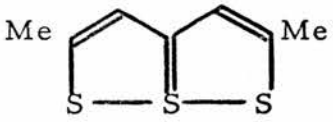

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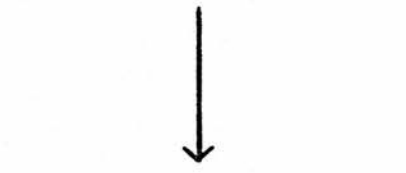

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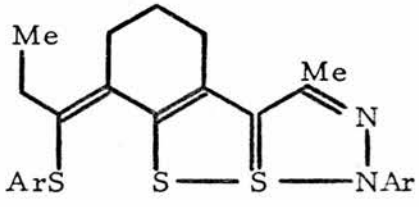

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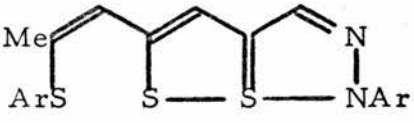


50

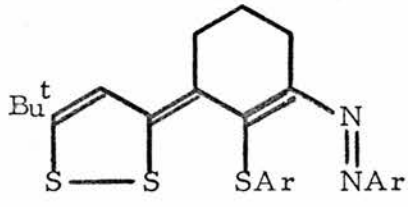
a. 39%, Ar=p-NO_2Ph
b. 0.5%, Ar=Ph

42%, Ar=p-NO_2Ph

+

9%, Ar=Ph

+



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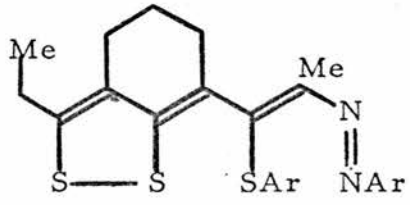

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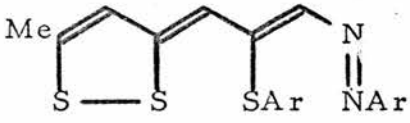


51

0%, Ar=Ph, p-NO_2Ph

3.5%, Ar=p-NO_2Ph

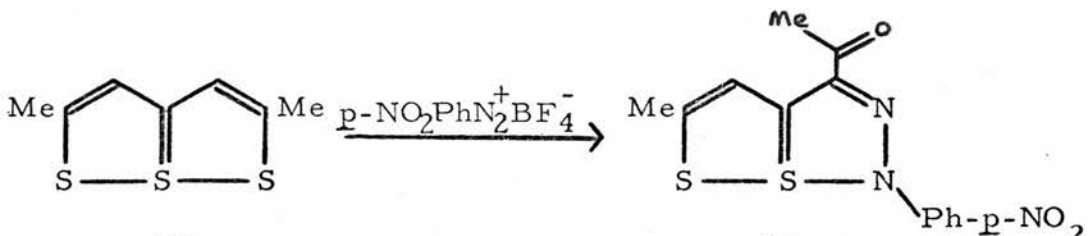
8%, Ar=Ph

The low yield is presumably due to the fact that the benzenediazonium ion is a weaker electrophile than the p-nitrobenzenediazonium ion.

In the same study[96] reaction of the trithiapentalene (46) with p-nitrobenzenediazonium tetrafluoroborate in methanol gave two products, (47) and (48), in 42% and 3.5% yields respectively.

Also the reaction of 2,5-dimethyl-1,6,6aλ^4-trithiapentalene (49) with benzenediazonium tetrafluoroborate in dimethylformamide gave the two products (50) and (51) in low but approximately equal yields. The low yields are probably due in part to the relatively low electrophilicity of the benzenediazonium cation and the smaller activating effect of methyl groups compared to other alkyl substituents, particularly t-butyl. In all the preceding reactions starting material was recovered in significant quantities.

In contrast to the immediately preceding reaction, 2,5-dimethyl-1,6,6aλ^4-trithiapentalene (49), when treated with p-nitrobenzenediazonium tetrafluoroborate in methanol, gave only the ketone (52) (64%) and starting material (9%).



49 52

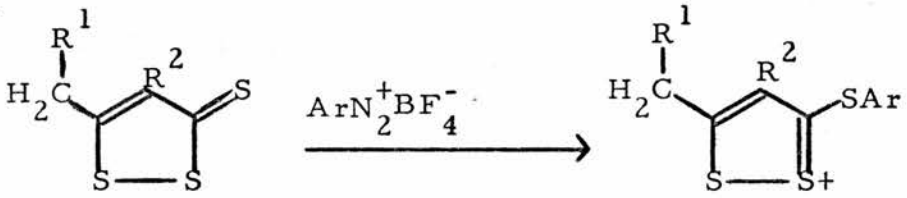
In all the foregoing reactions, with the exception of the last, arylthio intermediates of the type (39) have been trapped and the resulting products [(44), (47), (48), (50), (51)] isolated. This and the material of preceding sections summarises the main evidence available for electrophilic attack at sulphur in the reaction of trithiapentalenes with arenediazonium tetrafluoroborates. This evidence is fairly compelling, nevertheless, the dithiolium ion [e.g. (39)] resulting from initial attack at sulphur has not yet been

observed. Moreover, the multiplicity of reactions that can occur in the systems studied above (in this section) is potentially large, making desirable a study of related reactions with more limited outcomes.

DISCUSSION OF RESULTS

1. Reactions of 1,2-Dithiole-3-thiones with Arenediazonium Tetrafluoroborates

We decided to obtain further evidence for the proposed mechanism of the reaction of trithiapentalenes with arenediazonium tetrafluoroborates, which involves electrophilic attack at sulphur initially or concurrently with attack at C-3(4), by extending the study to 5-methyl(ene)-1,2-dithiole-3-thiones (1). The sulphur



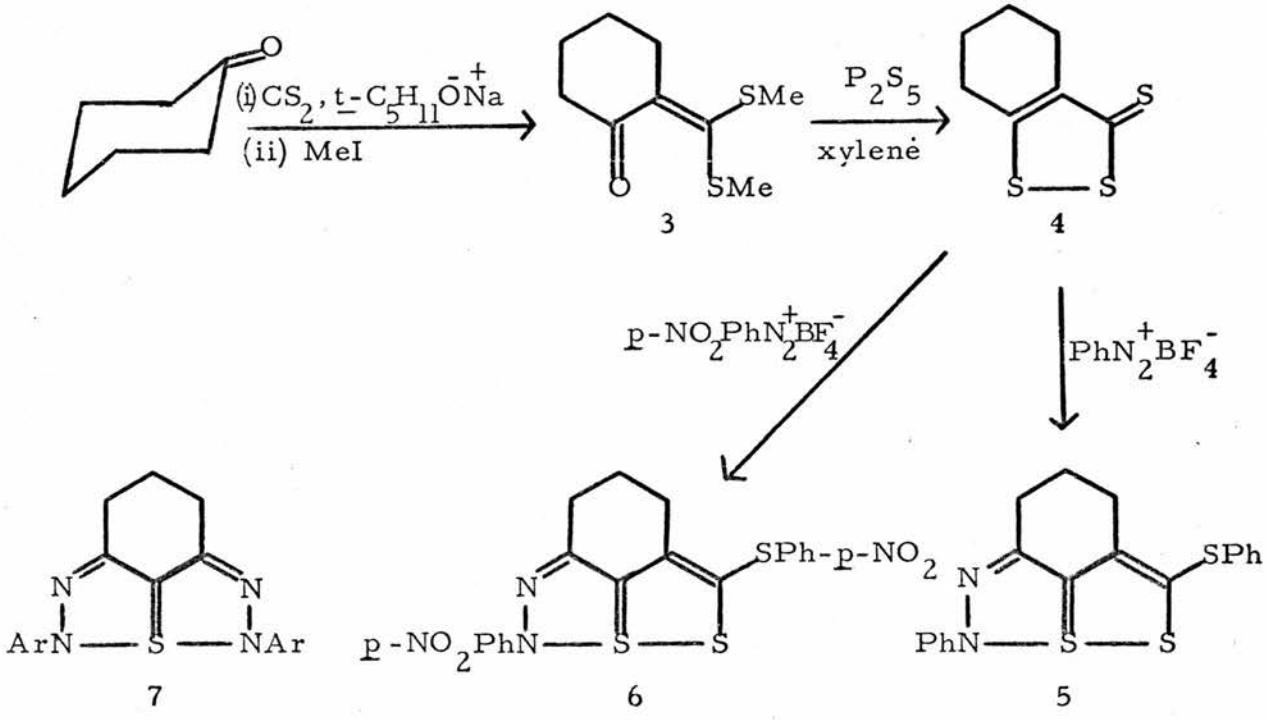
1 2

atom of the thiocarbonyl group is susceptible to electrophilic attack by arenediazonium ion, which would result (after elimination of nitrogen) in a dithiolium ion(2) having a methyl(ene) group activated to deprotonation and further attack. The trapping of this salt in the absence of a reactive methyl(ene) group (Bu^t instead of R^1CH_2) was also anticipated.

(a) 4,5,6,7-Tetrahydrobenzo[d]-1,2-dithiole-3-thione

One of the simplest 1,2-dithiole-3-thiones to study is 4,5,6,7-tetrahydrobenzo[d]-1,2-dithiole-3-thione (4), since the products from diazo-coupling, in this case compounds (5) and (6),

are blocked at the 3 and 4 positions and cannot undergo substitution at these positions by further reaction with the arenediazonium salt. Another product (7) resulting from diazo-coupling of the primary product (5) or (6) and concomitant elimination of the —CSSAr was considered possible, but was not observed in either of the reactions described below.

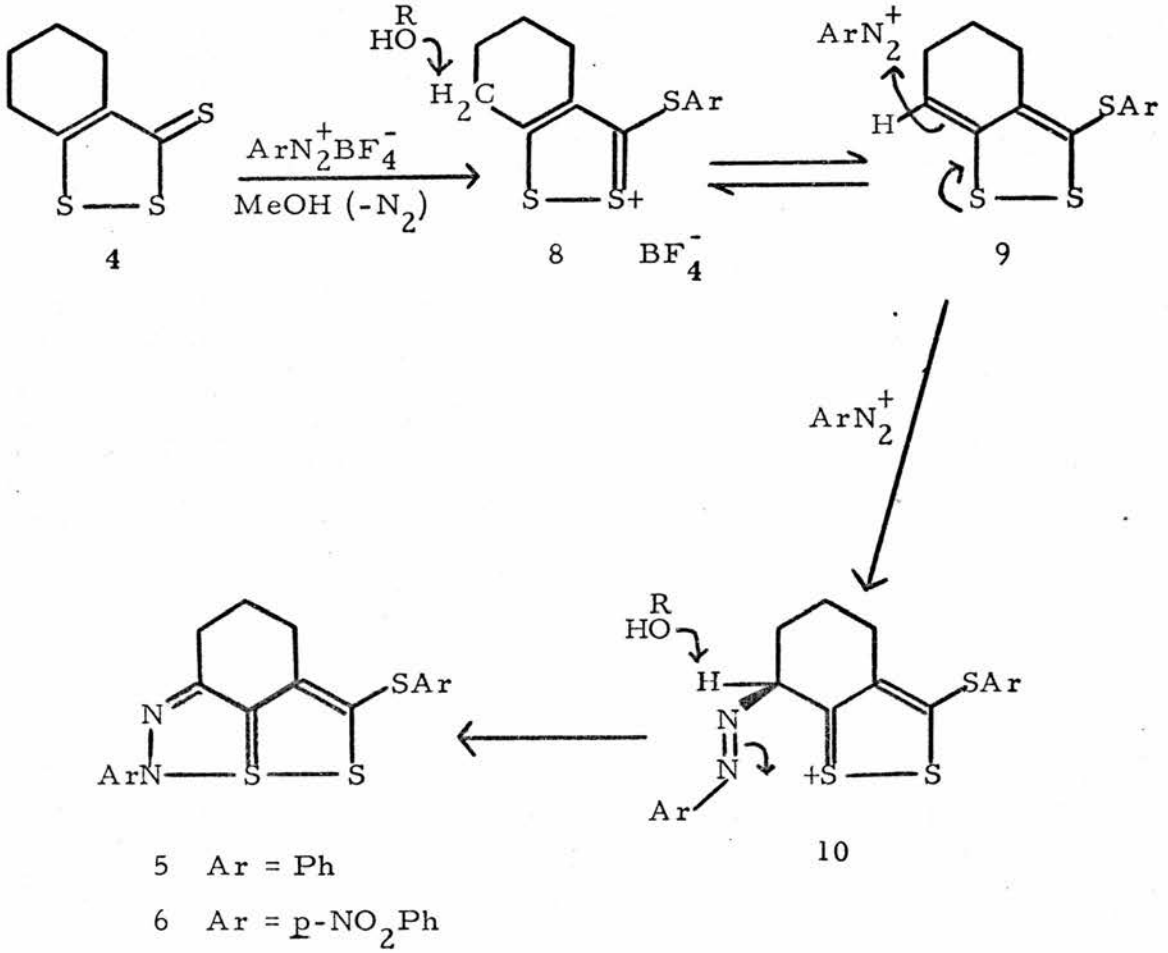


The thione (4) was prepared by a series of reactions adapted from the procedures of Thuillier and Vialle[97,98]. Treatment of cyclohexanone with carbon disulphide in the presence of sodium t-amylate, and then with methyl iodide gave 2-[bis(methylthio)methylene]cyclohexanone (3) in 57% yield. This ketone reacted with phosphorus pentasulphide in boiling xylene to give a 58% yield of the dithiolethione (4).

4,5,6,7-Tetrahydrobenzo[d]-1,2-dithiole-3-thione (4) reacted with benzenediazonium tetrafluoroborate in methanol at 50°C to give

the expected product (5) in 20% yield. The proposed mechanism (Scheme I) is exactly analogous to that postulated for the reaction of 1,6,6aλ^4-trithiapentalenes with arenediazonium tetrafluoroborates.

SCHEME I



5 Ar = Ph

6 Ar = p-NO_2Ph

Electrophilic attack at the thiocarbonyl group results in the dithiolium salt (8), whose 5-methyl(ene) group is activated to solvent-assisted deprotonation, which results in the neutral intermediate (9). Further attack by arenediazonium ion gives the intermediate (10), from which the product (5) is formed by loss of a proton. The arylthio substituent is sufficiently stable not to be hydrolysed under the reaction conditions. The benzenediazonium cation is a relatively weak electrophile, and this presumably accounts for the low yield

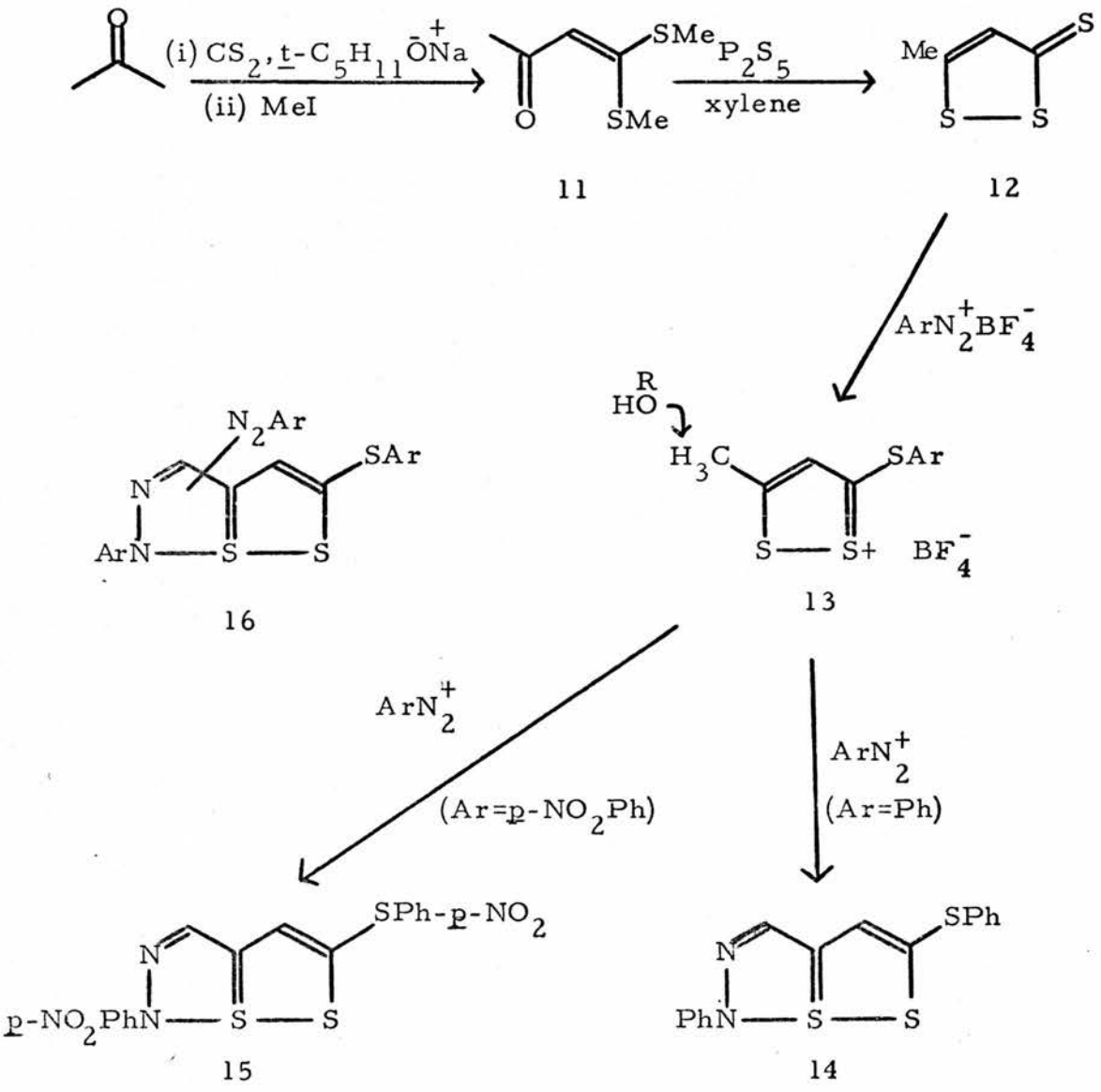
of the dithiadiazapentalene (5). In this reaction 58% of the starting material was recovered.

Reaction of the thione (4) with the more strongly electrophilic p-nitrobenzenediazonium tetrafluoroborate gave the dithiadiazapentalene (6) in 86% yield. This product crystallised from benzene as charge-transfer complex containing two molecules of compound to one of benzene, but it was found possible to obtain an uncomplexed sample by crystallisation from toluene.

(b) 5-Methyl-1,2-dithiole-3-thione

A modification of the procedure of Thuillier and Vialle[97,98] gave 5-methyl-1,2-dithiole-3-thione (12) from acetone and carbon disulphide via 1,1-bis(methylthio)but-1-en-3-one (11). The thione (12) was expected to react in the same manner as did the thione (4), except that in this case the 3 and 4 positions of the primary products are unsubstituted. This allows the possibility of further diazo-coupling of the product (14) or (15) to give a substitution product of the form (16), where the arylazo substituent may, in theory, be in either the 3 or 4 position, or both. Formation of the thiatetra-azapentalene analogous to structure (7) was not observed in the reactions of the thione (12) either.

5-Methyl-1,2-dithiole-3-thione reacted with benzenediazonium tetrafluoroborate in methanol at 50°C to give the dithiadiazapentalene (14) in 5.2% yield: starting material was recovered in 12% yield. The low yield of the product (14) is again probably due in part to the weakness of the benzenediazonium cation as an



electrophile. However, the thione (12) is relatively unstable, and its partial destruction under the reaction conditions would contribute both to its low recovery and to the low yield of product. A trace of a second product from this reaction was tentatively identified by its mass spectrum as the mono-substituted compound (16, Ar=Ph) resulting from further substitution of the primary product (14).

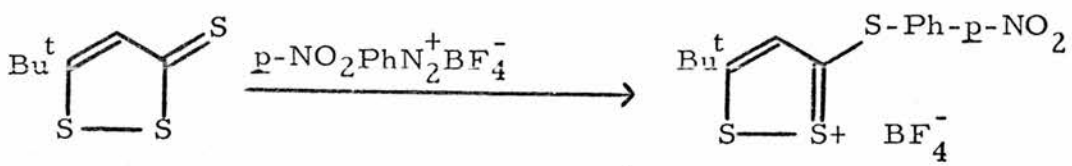
The reaction of the thione (12) with p-nitrobenzenediazonium

tetrafluoroborate gave the dithiadiazapentalene (15) in 34% yield. No starting material was recovered, and the possible further substitution product (16, Ar=p-NO_2Ph) was not observed. However, 4,4'-dinitrodiphenyldisulphide (p-NO_2PhSSPh-p-NO_2) was isolated in substantial amount, indicating that side reactions significantly decrease the yield of the desired product.

(c) 5-t-Butyl-1,2-dithiole-3-thione

The type of reaction discussed in (a) and (b) above is able to proceed to a neutral bicyclic product by virtue of the presence in the dithiolethiones (4) and (12) of a 5-methyl(ene) group. It was envisaged that a 1,2-dithiole-3-thione having a 5-substituent without protons adjacent to the ring would be arylated at sulphur in the same manner as was observed in the preceding examples, but that further diazo-coupling could not take place. Thus the reaction would stop at the dithiolium salt intermediate [cf. (8), Scheme I] and the S-arylation product would be trapped.

5-t-Butyl-1,2-dithiole-3-thione (17) reacted with



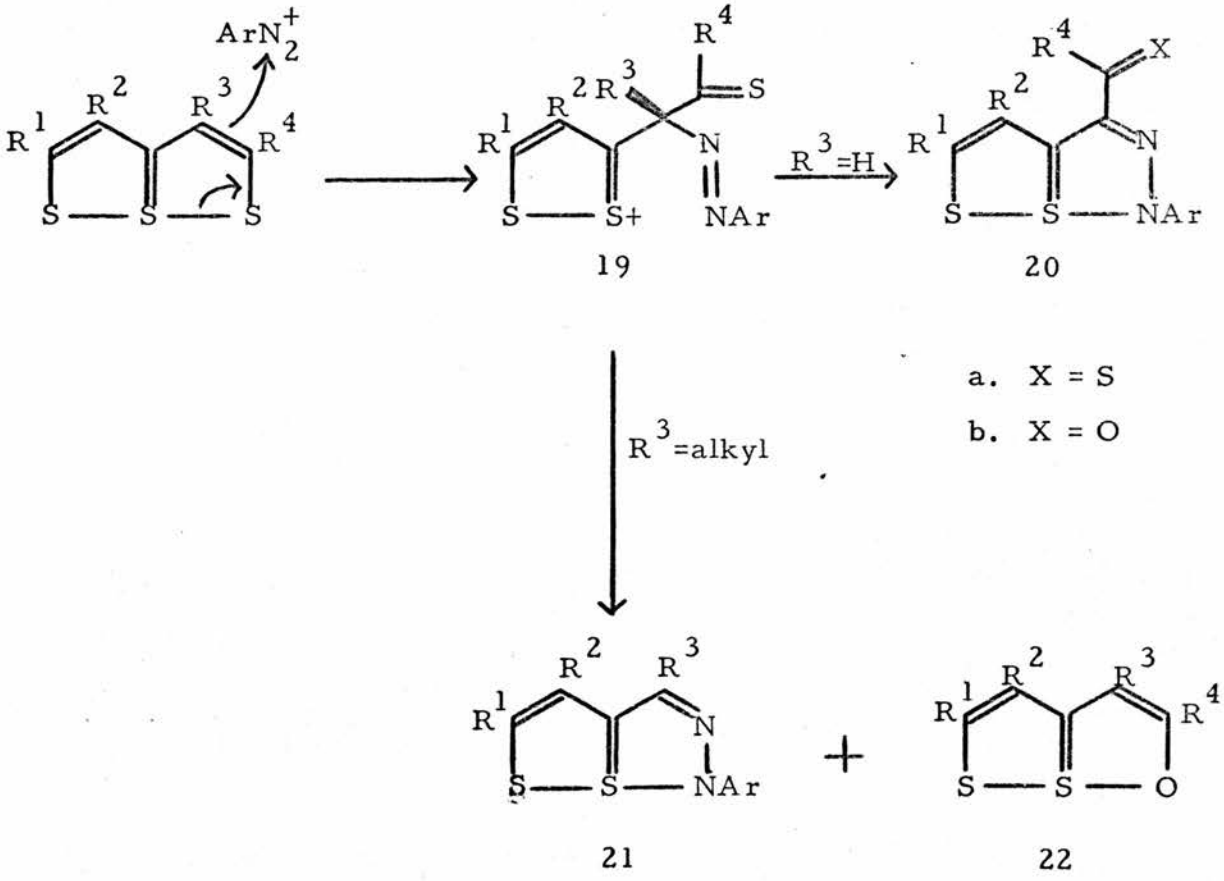
17 18

p-nitrobenzenediazonium tetrafluoroborate in acetonitrile at

50°C to give an 83% yield of the dithiolium salt (18). The product appeared to decompose when the reaction was carried out using methanol as solvent.

(d) Conclusions

A mechanism for the reaction of 1, 6, 6a λ^4-trithiapentalenes with arenediazonium cations has been suggested[54]. It involves electrophilic attack at C-3(4) to give the intermediate dithiolium



ion (19) which then gives rearrangement products. If R^3=H, a product (20) is formed whose nature depends on R^4. In the case where R^4=H a mixture of the thioaldehyde (20a) polymer and

the aldehyde (20b) is obtained. If R^4 is a group, SMe or NMe_2, capable of stabilising the thiocarbonyl group then the product (20a) is the corresponding dithioester or thioamide. Furthermore, the activating effect of the substituent (SMe or NMe_2) at C-2 promotes electrophilic substitution at C-3. If, on the other hand, R^3 is alkyl, then the R^4CS group is eliminated and the product is (21). This mechanism alone, however, does not account for the presence of the oxadithiapentalene (22) with the product (21). Nor does it account for the products of reactions discussed in section 5. of the discussion of background literature, above.

A mechanism involving electrophilic attack at sulphur and C-3 concurrently (with elimination of nitrogen) can account for all the products of the reactions of this type which have been studied. The proposed routes to these products are summarised in Scheme II, parts A, B and C. [Part A for attack at C-3(4)]

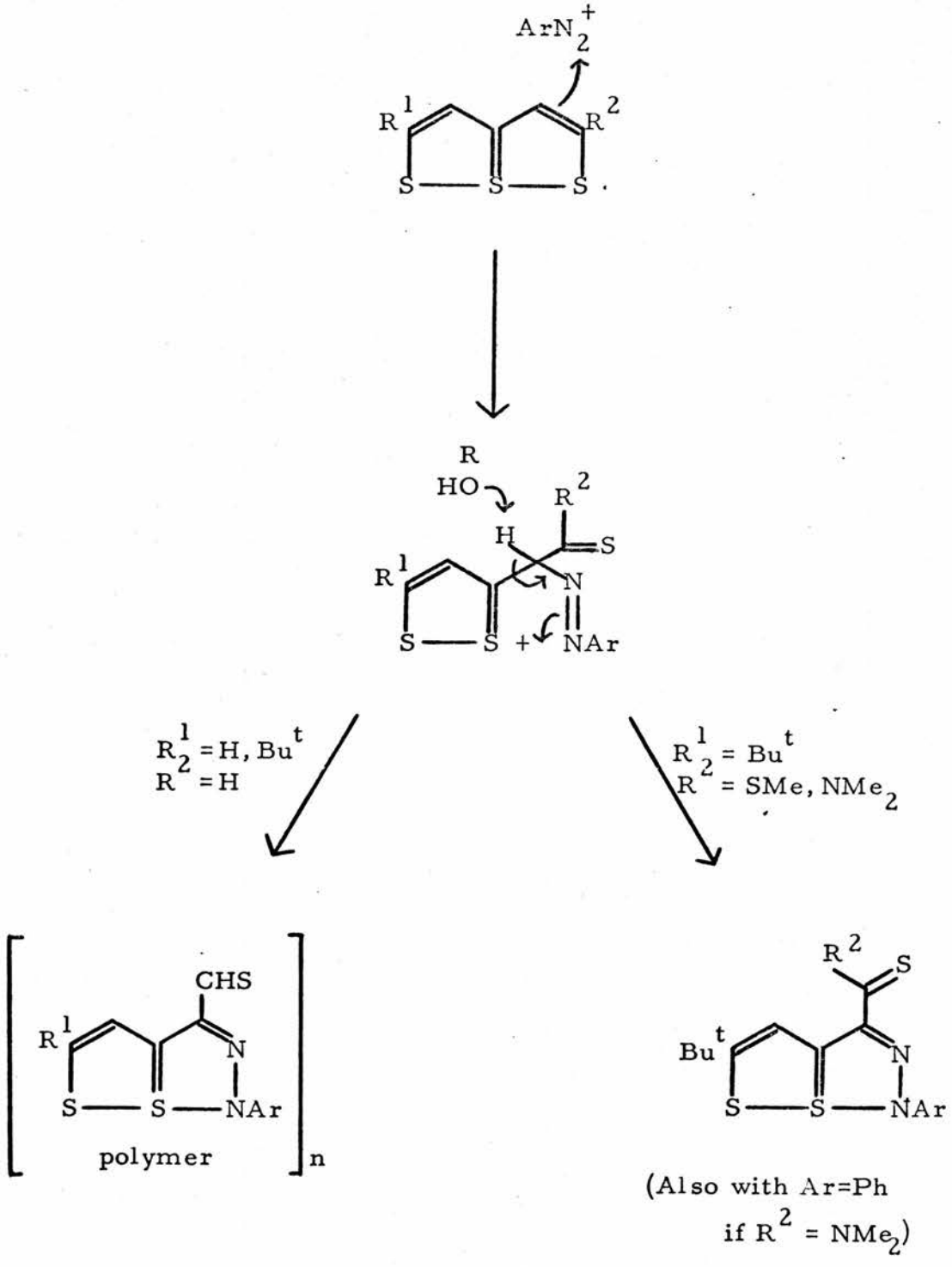
Strong support has been given to a mechanism involving attack at sulphur by the isolation of the S-arylation products (23) and (24) [Scheme II C] in those specially designed reactions[96], and we have further confirmed it by the simpler but exactly comparable reaction of 5-methyl(ene)-1,2-dithiole-3-thiones with the same electrophiles (Scheme III) and by trapping a dithiolium cationic intermediate as the salt (18).

The reaction of 5-methyl(ene)-1,2-dithiole-3-thiones with arenediazonium tetrafluoroborates also provides a convenient route to some 6,6aλ^4-dithia-1,2-diazapentalenes with a potentially removable arylthio substituent in the 5-position.

SCHEME II

REACTIONS OF TRITHIAPENTALENES WITH ARENEDIAZONIUM TETRAFLUOROBORATES

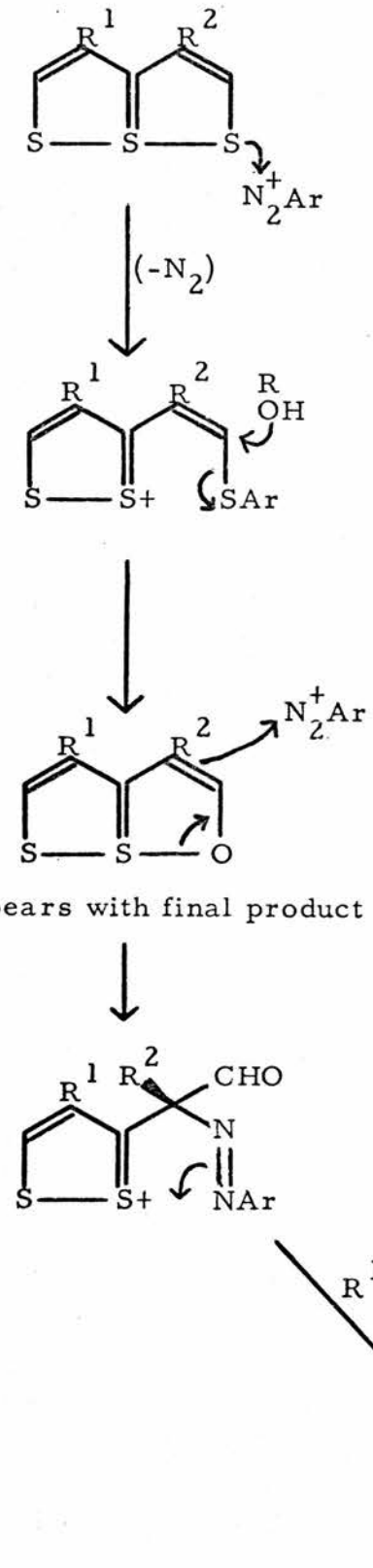
A



Ar = p-NO_2Ph

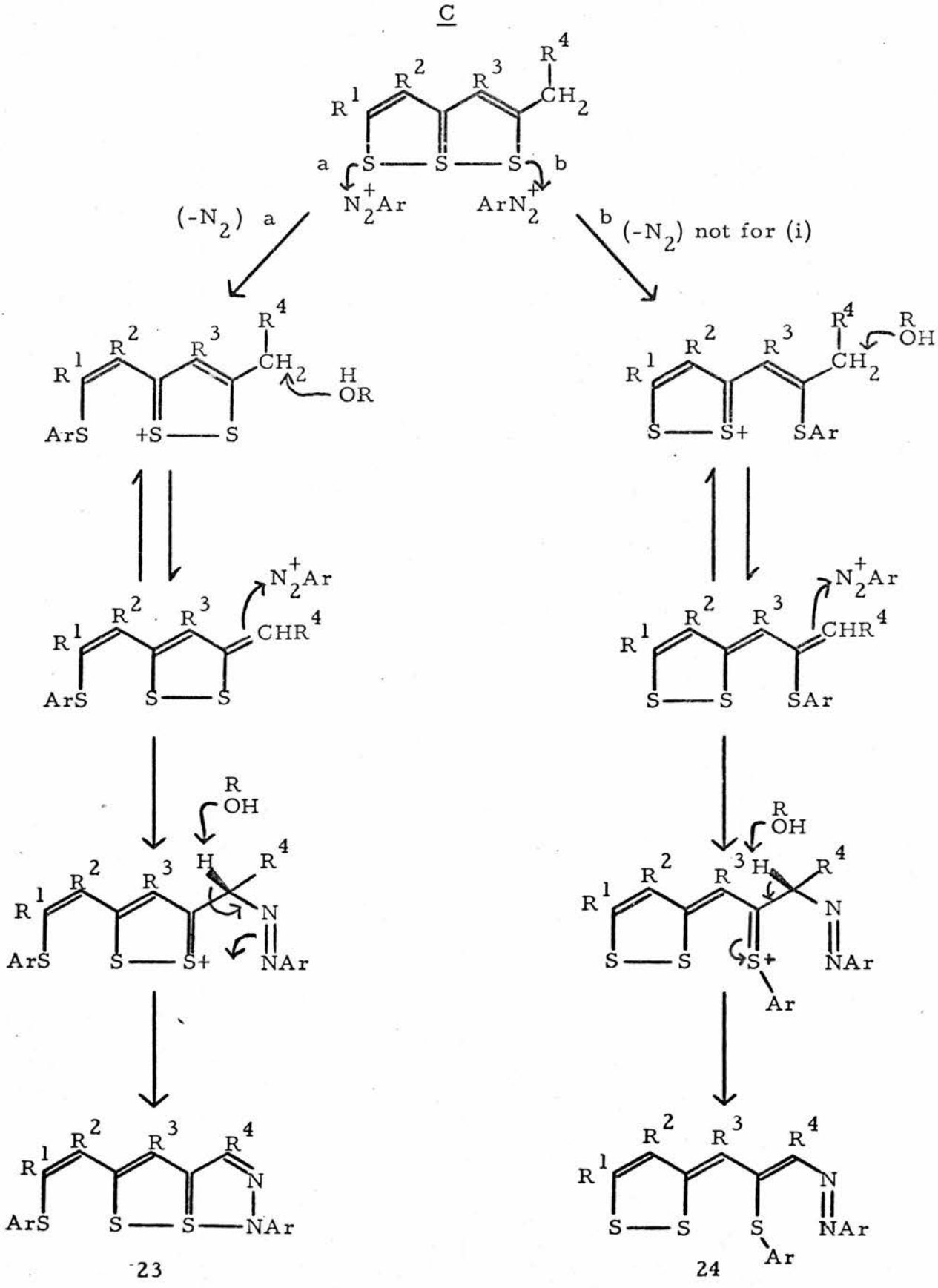
SCHEME II

B



Ar = p-NO_2Ph

SCHEME II



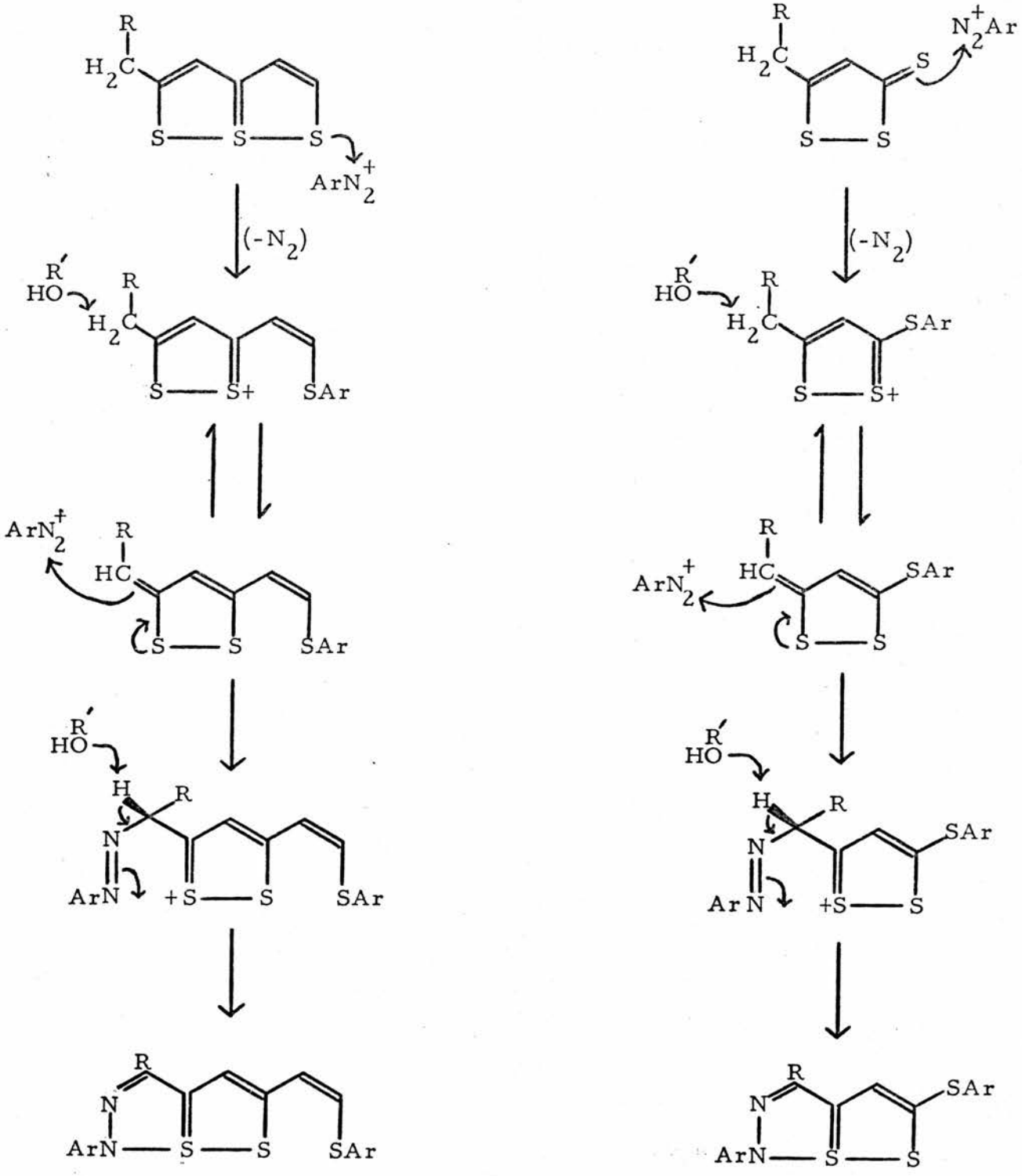
(i) R^1=Bu^t, R^2=H, R^3—R^4 = -$(CH_2)_4$-, Ar=Ph, p-NO_2Ph

(ii) R^1=R^4=Et, R^2—R^3= -$(CH_2)_3$-, Ar=p-NO_2 Ph

(iii) R^1=R^4=Me, R^2=R^3=H, Ar=Ph

SCHEME III

REACTION OF 2-METHYL(ENE)-1, 6, 6a λ^4-TRITHIAPENTALENES AND 5-METHYL(ENE)-1, 2-DITHIOLE-3-THIONES WITH ARENE-DIAZONIUM TETRAFLUOROBORATES: A COMPARISON



EXPERIMENTAL

(see Introductory Note to Experimental of Part I)

1. Preparation of 4, 5, 6, 7-Tetrahydrobenzo [d]-1, 2-dithiole-3-thione

(a) Preparation of 2- [Bis(methylthio)methylene]cyclohexanone

An approximately 2M solution of sodium t-amylate was prepared by adding clean sodium (46 g, 2 mol) to a solution of t-amyl alcohol (t-pentanol) (220 ml, 2 mol) in benzene (1 l). The mixture was heated carefully and refluxed for 60 h , after which time some unreacted sodium still remained. The warm solution was decanted from the sodium into a 3-neck 3 l RB flask fitted with a mechanical stirrer, drying tube, and thermometer, and then cooled to below 10°C in an ice water bath. Over a period of 15 min a mixture of carbon disulphide (60 ml, 1 mol) and cyclohexanone (104 ml, 1 mol) was added to the cooled t-amylate solution with stirring. The reaction was immediate and exothermic, and a large amount of a red-orange solid was formed. After stirring for 2 h below 10°C, benzene (600 ml) was added and the sludge was broken up to facilitate stirring. Over a period of 1 h methyl iodide (124.5 ml, 2 mol) was added with continued stirring and cooling. Stirring was then stopped, and the ice bath kept in place for 3 h , after which time it was removed to allow the mixture to warm to room temperature overnight. The reaction mixture was then poured into water (2 l)

which, after being separated from the benzene, was further extracted with benzene (1 l). The benzene layers were combined and washed with dilute sodium carbonate solution (1 x 1 l) and water (1 x 1 l). Evaporation of the benzene left a residue which was distilled to give 2-[bis(methylthio)methylene]cyclohexanone (3) as a yellow solid (115 g, 57%), b.p. = 136-140°C/4 mm Hg (lit.[97] 123-124°C/0.1 mm Hg).

(b) Preparation of 4,5,6,7-Tetrahydrobenzo[d]-1,2-dithiole-3-thione

Phosphorus pentasulphide (200 g, 900 mmol) was added in portions to xylene (900 ml) in a 3-neck 3 l RB flask, with stirring. As stirring continued the mixture was heated nearly to boiling. Then, over a period of 20 min, a solution of 2-[bis(methylthio)methylene]cyclohexanone (3) (60.697 g, 300 mmol) in xylene (300 ml) was added, following which the mixture was refluxed for 30 min and then allowed to cool overnight. The solid material in suspension was filtered off and washed with ether and hot benzene. The organic filtrates were washed twice with sodium carbonate solution, once with water, dried and evaporated to a small volume. (STENCH - recommend drawing off-gases through sodium hypochlorite solution) The resulting dark oil was dissolved in benzene and adsorbed onto a column of alumina (30 x 5.5 cm). The column was then eluted with petrol/benzene (3:1). Only the initial 2 l of eluates were retained and evaporated to dryness. The residual solid was crystallised from cyclohexane, and the crystals obtained

were recrystallised from cyclohexane. The solid from the combined two lots of mother liquors was also crystallised from cyclohexane. These two crops gave 4,5,6,7-tetrahydrobenzo[d]-1,2-dithiole-3-thione (4) (32.806 g, 58%) as large orange spars.

^{1}H nmr, ($CDCl_3$): unexpanded spectrum

δ 1.80 (4H, m, 5-H_2 and 6-H_2), 2.58 (2H, m, 4-H_2 or 7-H_2), 2.82 (2H, m, 7-H_2 or 4-H_2)

2. Preparation of 5-Methyl-1,2-dithiole-3-thione

(a) Preparation of 1,1-bis(methylthio)but-1-en-3-one

An approximately 2 M solution of sodium t-amylate was prepared as described for the preparation of 4,5,6,7-tetrahydrobenzo[d]-1,2-dithiole-3-thione. After the solution had been decanted from the residual sodium and cooled below 10°C a mixture of carbon disulphide (60 ml, 1 mol) and acetone (74 ml, 1 mol) was added over a 15 min period, with mechanical stirring. After 2.5 h , and with continued stirring and cooling, methyl iodide (124.5 ml, 2 mol) was added over a 1 h period. A further 2 h elapsed before the stirring was stopped, the ice bath was removed, and the reaction was allowed to stand at room temperature overnight. The mixture was poured into water (2 l), which, after separation of the benzene layer, was further extracted with benzene (1 x 1 l). The combined benzene layers were washed with dilute sodium carbonate solution (1 x 1 l) and water (1 x 1 l), and evaporated to low volume. The residue was distilled (116-120°C/ca. 0.1 mm Hg) giving 1,1-bis(methylthio)but-1-en-3-one (11) (39.095 g, 24%).

(b) Preparation of 5-Methyl-1,2-dithiole-3-thione

Phosphorus pentasulphide (160 g, 720 mmol) was added portionwise to xylene (700 ml) stirred in a 3-neck 3 l RB flask. This mixture was heated to near boiling and a solution of 1,1-bis-(methylthio)but-1-en-3-one (11) (38.947 g, 240 mmol) in xylene (250 ml) was added over 20 min. After being refluxed and stirred

for 30 min and then allowed to cool for 2.5 h the reaction mixture was filtered and the solid was washed with ether and hot benzene. The combined organic filtrates were washed with aqueous sodium carbonate (caution!, foaming) (2 x 500 ml) and water (1 x 500 ml), dried and evaporated. (STENCH; recommend drawing off gases through sodium hypochlorite solution) The resulting oil was passed through a column of alumina (ca. 30 x 5.5 cm) with petrol/benzene (1:1) (ca. 7 l) and benzene (7 l) as eluant, respectively. All yellow eluates were combined and evaporated. The residual oil was repeatedly extracted with boiling petroleum ether, leaving a dark insoluble oil. The petroleum extracts were evaporated on a rotary evaporator without heating, and the residue was chromatographed on a column of silica gel (55 x 4 cm). Elution with petrol/benzene (2 l, 2:1) and (1.5 l, 1:1) gave red-orange eluates which were discarded. Elution with benzene (and later a few percent ether in benzene) gave yellow eluates which, on evaporation, provided 5-methyl-1,2-dithiole-3-thione (12) (13.56 g, 38%) as a yellow oil which crystallised in the freezer.

^{1}H nmr, ($CDCl_3$): unexpanded spectrum

δ 2.50 (3H, s, 5-Me), 7.20 (1H, bs, 4-H)

3. Preparation of Arenediazonium Tetrafluoroborates

(a) Preparation of Benzenediazonium Tetrafluoroborates

Aniline (22.8 ml, 250 mmol) was dissolved in a mixture of conc. hydrochloric acid (100 ml) and water (250 ml) and the filtered solution was cooled to 0°C in an ice-salt bath. Filtered sodium nitrite solution (5 M, 50 ml), was added dropwise to the aniline solution, keeping the temperature below 5°C. Excess nitrous acid was then destroyed by addition of urea. The solution was then filtered rapidly and fluoroboric acid (75 ml as 40% soln.) was added. The mixture was kept in the ice-salt bath for 1 h longer. The precipitated salt was filtered off, washed with a little water, twice with ethanol, and then with ether. The salt was dried in vacuo. This gave benzenediazonium tetrafluoroborate (30.35 g, 63%).

(b) Preparation of p-Nitrobenzenediazonium Tetrafluoroborate[99]

p-Nitroaniline (34.530 g, 250 mmol) was dissolved in fluoroboric acid (500 ml as 20% soln.) and the filtered solution was cooled in an ice bath. A cold filtered solution of sodium nitrite (17.250 g, 250 mmol) in water (40 ml) was added dropwise with stirring. When addition was complete the mixture was stirred for a further 5 min. The precipitated salt was filtered off, washed with a little cold filtered fluoroboric acid soln., twice with ethanol, several times with ether, and dried. This gave p-nitro benzenediazonium tetrafluoroborate (54.50 g, 92%) as pale yellow crystals.

4. Reactions of 1,2-Dithiole-3-thiones with Arenediazonium Tetrafluoroborates

General Procedure:

The thione (10 mmol) was dissolved, with magnetic stirring, in methanol (160 ml) at 50°C (water bath). The arenediazonium tetrafluoroborate (40 mmol) was then added with washings of pre-warmed methanol (40 ml), and stirring was continued at 50°C for 30 min. The reaction mixture was poured into an excess of aqueous sodium carbonate. Subsequent work-up is described for each reaction.

(a) Reaction of 4,5,6,7-Tetrahydrobenzo[d]-1,2-dithiole-3-thione with Benzenediazonium Tetrafluoroborate

4,5,6,7-Tetrahydrobenzo[d]-1,2-dithiole-3-thione (4) (1.885 g, 10 mmol) and benzenediazonium tetrafluoroborate (7.678 g, 40 mmol) were used. The reaction mixture in aqueous sodium carbonate was extracted with benzene (2 x 500 ml + 1 x 200 ml). The extracts were washed with water (2 x 500 ml), dried and evaporated. The residue was chromatographed on alumina (50 x 2.7 cm) using petrol as eluant. The first 3 l of eluates were discarded. The next 13.5 l of eluates contained substrate (1.212 g, 64%). Subsequently a small quantity of benzene was added to the eluant. The next 3 l of eluates were discarded. Elution with petrol/benzene (700 ml, 1:1) and benzene (500 ml) gave a fraction containing mostly the desired product (5). After

evaporating the solvent from this last fraction, the residual solid was crystallised from cyclohexane giving 1-phenyl-4,5-dihydro-3H-benzo[cd]-5-phenylthio-6,6aλ^4-dithia-1,2-diazapentalene (5) (728 mg, 20%) as purple prisms (also dark red plates), m.p. = 122.5-125.5°C.

Found: C, 62.0; H, 4.5; N, 7.5%

$C_{19}H_{16}N_2S_3$ requires: C, 61.9; H, 4.4; N, 7.6%

Accurate mass determination 368.0478

$C_{19}H_{16}N_2S_3$ requires 368.0476

^{1}H nmr, ($CDCl_3$): δ 2.10 (2H, quint., 4-H_2), 3.02 (4H, bt, 3-H_2 and 5-H_2), 7.12 to 7.71 (10H, m-complex, o-, m-, and p-protons of two phenyl groups)

uv spectrum, (cyclohexane): λ_{max} (nm) 522 (log ϵ 4.47), 349 pl (3.48), 296 (4.07), 234 (4.57), 206 (4.55)

The crude starting material from the column was crystallised from cyclohexane giving the thione (4) (1.095 g, 58%).

(b) Reaction of 4,5,6,7-Tetrahydrobenzo[d]-1,2-dithiole-3-thione with p-Nitrobenzenediazonium Tetrafluoroborate

4,5,6,7-Tetrahydrobenzo[d]-1,2-dithiole-3-thione (1.884 g, 10 mmol) and p-nitrobenzenediazonium tetrafluoroborate (9.478 g, 40 mmol) were used. After addition to aqueous sodium carbonate the reaction mixture was filtered through a glass-wool plug and extracted with benzene (6 x 1 l). The last 2 l of benzene were boiled before being used for the extraction, and this hot benzene was also used to extract the sludge which had been filtered off.

The extracts were divided into two portions, each of which was washed with water (2 x 1 l), dried and evaporated. The residual solids from these two portions of extracts were combined and crystallised from benzene, giving dark red prisms (4.266 g) calculated from analysis (q.v.) to be a charge-transfer complex containing 1 molecule of benzene per two molecules of desired product (6). This corresponds to an 86% (3.931 g) yield of product (6).

Found (complex): C, 53.1; H, 3.2; N, 11.5%

$C_{44}H_{34}N_8O_8S_6$ (complex) requires: C, 53.1; H, 3.4; N, 11.3%

A sample of this charge-transfer complex was recrystallised from toluene, which resulted in dark red arc-shaped micro-needles of 1-p-nitrophenyl-4,5-dihydro-3H-benzo[cd]-5-p-nitrophenylthio-6,6aλ^4-dithia-1,2-diazapentalene (6), m.p. = 243-244°C.

Found: C, 49.5; H, 3.0; N, 12.1%

$C_{19}H_{14}N_4O_4S_3$ requires: C, 49.8; H, 3.1; N, 12.2%

Accurate mass determination 458.0187

$C_{19}H_{14}N_4O_4S_3$ requires 458.0177

^{1}H nmr, (dmso-D_6, 160°C): 0.2M, hexamethyldisiloxane reference:

δ 2.09 (2H, quint., 4-H_2), 3.03 (4H, m, 3-H_2 and 5-H_2), 7.66 and 7.73 (2H, ortho-protons of one p-nitrophenyl group), 7.76 and 7.84 (2H, ortho-protons of other p-nitrophenyl group), 8.11 and 8.21 (4H, superimposed, meta-protons of both p-nitrophenyl groups)

uv spectrum, (cyclohexane) saturated soln.: λ_{max} (nm), 537, 344, 233, 222 sh, 201

(c) Reaction of 5-Methyl-1,2-dithiole-3-thione with Benzenediazonium Tetrafluoroborate

5-Methyl-1,2-dithiole-3-thione (12) (1.482 g, 10 mmol) and benzenediazonium tetrafluoroborate (7.678 g, 40 mmol) were used. After pouring into aqueous sodium carbonate, the reaction mixture was extracted with boiling benzene (2 x 500 ml). The extracts were washed with water (2 x 500 ml), dried, and evaporated. The residue was chromatographed on alumina (70 x 2.7 cm) (column I) with petrol/benzene (1:1) as initial eluant. The first 4.5 l of eluates were discarded. The solid from the next 4 l of eluates was rechromatographed on silica-gel (50 x 2 cm) (column II) with the same eluant. The first 1.3 l of eluates from column II were evaporated and the residual solid was crystallised from n-hexane to give 1-phenyl-5-phenylthio-6,6aλ^4-dithia-1,2-diazapentalene (14) (172 mg, 5.2%) as red micro-prisms, m.p. = 104-115°C. (The mother liquors after the 1st crop were passed through a short column of silica-gel with benzene before further recrystallisation. Both crops are included in the yield given.)

Found: C, 58.4; H, 3.8; N, 8.7%

$C_{16}H_{12}N_2S_3$ requires: C, 58.5; H, 3.7; N, 8.5%

Accurate mass determination 328.0149

$C_{16}H_{12}N_2S_3$ requires 328.0163

^{1}H nmr, ($CDCl_3$): δ 7.13 (1H, s, 3-H or 4-H), 7.22 to 7.75 (10H, m-complex, o-, m- and p-protons of two phenyl groups), 8.06 (1H, s, 4-H or 3-H)

uv spectrum, (cyclohexane): λ_{max} (nm) 500 (log ϵ 4.31), 352 (3.66), 282 (4.11), 236 (4.57), 206 (4.52)

The next 450 ml of eluates from column II were discarded, while the last 500 ml, obtained on elution with benzene and benzene/ether (19:1), gave starting material (12) (180 mg, 12%) on evaporation (identified by tlc and nmr).

A final 1 l of eluates was collected from column I with benzene as eluant. The solid from this fraction was rechromatographed on silica-gel (50 x 1.5 cm) (column III) using petrol/benzene (9:1) as initial eluant. The eluant was changed to 25%, 50% and 75% benzene in petrol at 800 ml intervals, and then to benzene after 200 ml. All eluates from this column (III) were discarded except the last 200 ml, which was eluted with benzene. Evaporation of these eluates gave a residue which was crystallised from cyclohexane yielding a few small crystals. The mass spectrum of this material (M^+ = 432) suggested that it may have been a further (mono-)substituted product (16).

(d) Reaction of 5-Methyl-1, 2-dithiole-3-thione with p-Nitrobenzenediazonium Tetrafluoroborate

5-Methyl-1, 2-dithiole-3-thione (12) (1.483 g, 10 mmol) and p-nitrobenzendiazonium tetrafluoroborate (9.475 g, 40 mmol) were used. The reaction mixture was filtered (Büchner funnel) into 1 l aqueous sodium carbonate and the resulting solution was extracted with boiling benzene (2 x 500 ml). The benzene extracts were washed with water (2 x 500 ml), dried, and evaporated. The residual

solid was combined with the solid initially filtered off and this material was added to a column of alumina (30 x 4 cm) (column I) in a large volume of warmed benzene. The first 1.5 l of eluates gave, on evaporation, a mixture of a solid and nitrobenzene (by smell). This mixture was separated by passing it through a column of silica gel (40 x 2.7 cm) with benzene as eluant, and then by crystallising the solid twice from benzene. This gave 4,4'-dinitrodiphenyldisulphide (finally 475 mg; 566 mg before the final recrystallisation) as colourless prisms, m.p. = 180.5-182°C (C.R.C. Handbook gives 182°C), M^+ = 308.

^{1}H nmr, ($CDCl_3$): δ 7.59 and 7.68 (4H, d with inside lines, ortho-protons of two p-nitrophenyl groups), 8.17 and 8.26 (4H, d with inside lines, meta-protons of two p-nitrophenyl groups).

The second fraction (200 ml) from column I contained relatively pure desired product (15). The third fraction (1.2 l) was evaporated and the residue rechromatographed on alumina (30 x 2.7 cm) (column II), giving 3 l of red eluates (benzene elution) which were combined with fraction 2 of column I. The solid from these combined eluates was recrystallised from benzene giving product (15) (1.373 g) in two crops. The final eluates from columns I and II, which were eluted with a few percent methanol in benzene, were combined and chromatographed on alumina (15 x 2.7 cm) (column III) with benzene as eluant. The first 1.7 l of eluates from column III were combined with the mother liquors from the product recrystallisation (above) and rechromatographed on alumina (20 x 2.7 cm) (column IV) with benzene as eluant. The initial 2.5 l of

eluates from column IV were evaporated, and the residual solid was crystallised from benzene giving a small (41 mg) third crop of product (15). The reaction thus provided 1-p-nitrophenyl-5-p-nitrophenylthio-6, 6a λ^4-dithia-1, 2-diazapentalene (15) (1.414 g, 34%) as dark red micro-prisms, m.p. = 224-226°C.

Found: C, 46.2; H, 2.3; N, 13.3%

$C_{16}H_{10}N_4O_4S_3$ requires: C, 45.9; H, 2.4; N, 13.4%

Accurate mass determination 417.9852

$C_{16}H_{10}N_4O_4S_3$ requires 417.9864

^{1}H nmr (dmso-D_6, 160°C): 0.2 M, hexamethyldisiloxane reference, δ 7.80 (s, 4-H), 8.66 (s, 3-H), 7.76, 7.85 and 7.95 (overlapping, ortho-protons of two p-nitrophenyl groups), 8.18 and 8.27 (superimposed, meta-protons of two p-nitrophenyl groups)

not sufficiently soluble for uv spectrum.

(e) Reaction of 5-t-Butyl-1, 2-dithiole-3-thione with p-Nitrobenzenediazonium Tetrafluoroborate

In a departure from the general procedure, acetonitrile was used instead of methanol for this reaction. To a magnetically stirred solution of 5-t-butyl-1, 2-dithiole-3-thione (17) (951 mg, 5 mmol) in acetonitrile (50 ml) at 50°C was added p-nitrobenzenediazonium tetrafluoroborate (1.184 g, 5 mmol), and the reaction mixture was stirred at 50°C for 30 min. Then the reaction mixture was refluxed on a water bath for 15 min and poured into ether (250 ml). The copious white precipitate was filtered off, washed

with ether, and dried in vacuo. It was then dissolved in a small volume of boiling acetonitrile, allowed to cool, and reprecipitated with ether. The solid was filtered off and dried, giving 5-t-butyl-3-p-nitrophenylthio-1,2-dithiolium tetrafluoroborate (18) (1.650 g, 83%), white flakes, m.p. = 215-224°C dec. .

Found: C, 39.2; H, 3.5; N, 3.4%

$C_{13}H_{14}NO_2S_3BF_4$ requires: C, 39.1; H, 3.5, N, 3.5%

^{1}H nmr, (CF_3COOH): 0.4 M, δ 1.68 (9H, s, t-butyl), 8.11 and 8.20 (2H, d with inside lines, ortho-protons of p-nitrophenyl group), 8.27 (1H, s, 4-H), 8.57 and 8.66 (2H, d with inside lines, meta-protons of p-nitrophenyl group)

uv spectrum, (methanol): λ_{max} (nm) 347 (log ϵ 3.96), 303 (4.01), 206 (4.17)

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