Some Uses of Cyclic Sulphones in Organic Synthesis

by

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To

My Mother & My Sister

'He had read Shakespeare
and found him weak in Chemistry.'

H.G. WELLS,   The Lord of the Dynamos

SUMMARY

The thermolysis and photolysis of a number of cyclic sulphones has been studied, with a view to developing these reactions as possible synthetic processes.

Some substituted dihydronaphthothiophene sulphones were prepared and those containing a pent-4-ene sidechain successfully underwent intramolecular Diels-Alder cyclisations.

2-Phenylthietan was prepared by a new route and the preparation and pyrolysis of some 2-phenylthietan 1,1-dioxide derivatives was studied.

Some 2-(alkan-1-ol) 3,3-dimethylthietan sulphones were prepared and the dehydration of these, with a view to preparing alk-1-ene derivatives, was studied. Phosphorus oxychloride in pyridine was the most successful of those reagents tried. The alk-1-ene derivatives were shown to have unusual thermal behaviour, when they ring-expanded to their respective sultines under flash vacuum thermolysis conditions.

The use of 3,3-dimethylthietan 1,1-dioxide as a starting material for a new route to chrysanthemates has been studied. Methyl-trans-chrysanthemate was eventually identified as one of the products after a 4-step synthesis from this sulphone.

A number of cyclic sulphides were prepared using phase transfer catalysis.

Certain abbreviations have been used in this thesis. They are -

g.l.c. - gas-liquid chromatography

t.l.c. - thin-layer chromatography

DMSO - dimethyl sulphoxide

HMPT - hexamethylphosphoric triamide

THF - tetrahydrofuran

LDA - lithium diisopropylamine

n.m.r. -   nuclear magnetic resonance

TBAB - tetrabutylammonium bromide

CTEAC - cetyltriethylammonium chloride

BTEAC - benzyltriethylammonium chloride
IMS - industrial methylated spirit

CONTENTS

CHAPTER ONE

PREPARATION AND PYROLYSIS OF SOME 1,3-DIHYDRONAPHTHOTHIOPHENE 2,2 DIOXIDES

1.1 Introduction

Thermal fragmentations of a 5 membered ring (1) (where Y is a small molecule such as N_2, CO, SO_2) to give a diene (2) have been known for many years[1]. Ring opening is typically disrotatory eg, for diazenes[2].
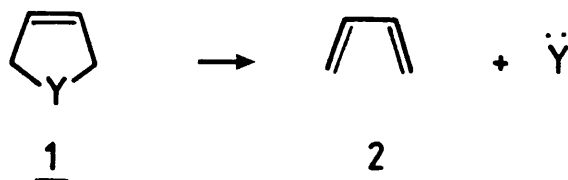
Extrusion of sulphur dioxide from a 2,5-dihydrothiophene 1,1,-dioxide is also a concerted disrotary elimination. Compounds (3) and (4) give the trans,trans-2,4-hexadiene (5) and the cis,trans-diene (6) respectively with greater than 99.9% stereospecificity[3].
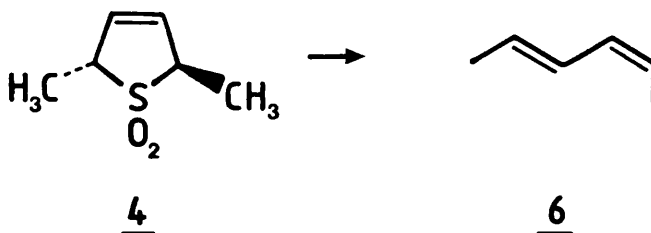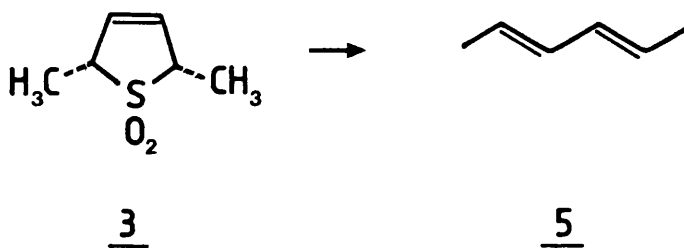
This type of concerted elimination has been extended to the cis and
trans stereoisomers of 2,7-dimethyl 2,7-dihydrothiepin 1,1-dioxides,
(7) and (8), which give cis,cis,trans-2,4,6-octatriene (9) and trans,
cis,trans-2,4,6-octatriene (10) respectively[4].
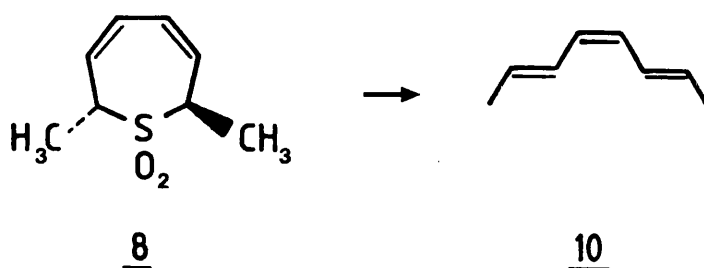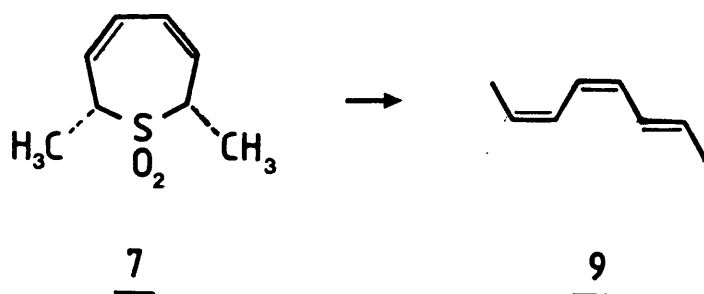
The stereospecificity of 97-99% represented a slight decrease but
could be accounted for by a change in conditions. The thiophene
sulphones were pyrolysed at nearer to equilibrium conditions, whereas
the octatrienes were the products of flash thermolyses at temperatures
significantly above the minimum decomposition temperatures. The
elimination of sulphur dioxide for 2,5-dihydrothiophene 1,1-dioxides
proceeds suprafacially, but for 2,7-dihydrothiepin 1,1-dioxides an
antarafacial chelotropic cycloregression is required to explain the
stereochemistry of the octatrienes.

However, stereospecificity is lost in the photolysis of dihydrothiophene 1,1-dioxides. Photolysis in benzene of compounds (11), (12) and (13) gives a mixture of dienes[5] (Scheme 1).
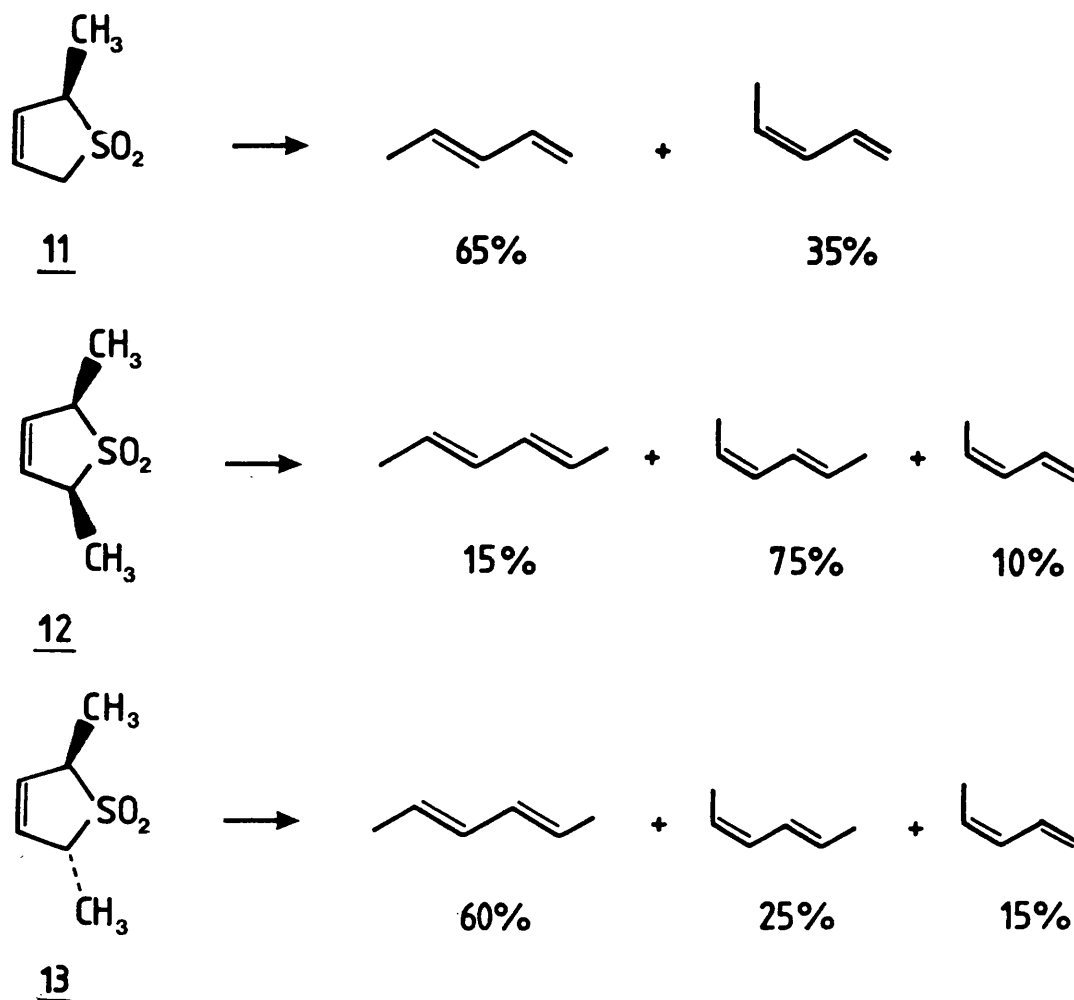
Scheme 1

Cava and Deana[6] were the first to demonstrate the elimination of sulphur dioxide from fused ring aryl sulphones when they thermolysed 1,3-dihydrobenzo[c]thiophene 2,2-dioxide (14) to give benzocyclobutene (15) and benzocyclooctadiene (16) as the major products in the gas phase and in solution respectively.
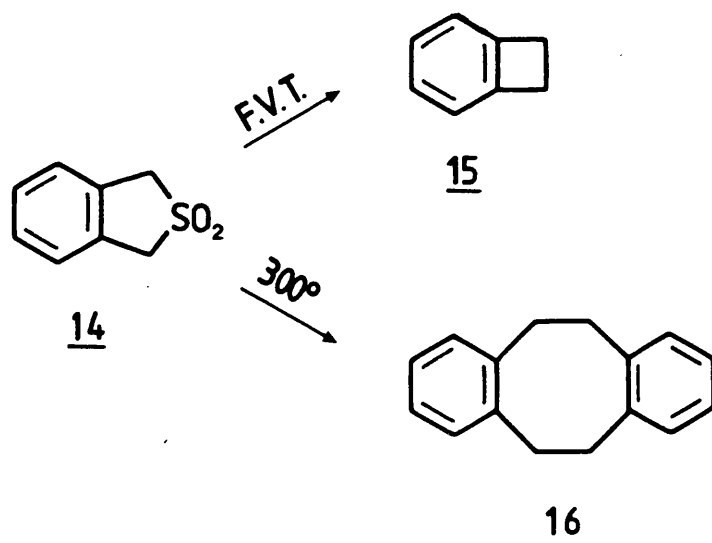
Whereas the extrusions of sulphur dioxide from benzylic positions and subsequent reactions are generally regarded as proceeding via benzyl radicals (this will be discussed in Chapter (2)), the behaviour of 1,3-dihydrobenzothiophene 1,1-dioxides is significantly different and hence a different type of reaction mechanism is proposed. These sulphones are regarded as giving o-quinodimethanes as intermediates on loss of sulphur dioxide. Cava trapped the o-quinodimethane from (14) with N-phenyl maleimide[6] (Scheme 2).
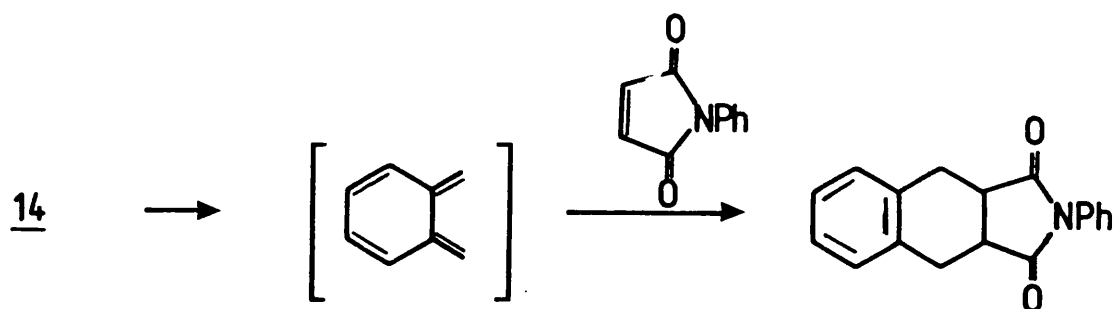
Scheme 2

Thermolysis of 1,3-dihydronaphtho[2,3-c]thiophene 1,1-dioxide (17) in solution gave the cyclobutene (18) rather than a dimer[7]. Because

-4-

the o-quinodimethane would involve greater loss of delocalisation than in the case of (14), the intermediate is believed to involve greater diradical character, resulting in a more rapid intramolecular ring closure to the cyclobutene.

17   **18**
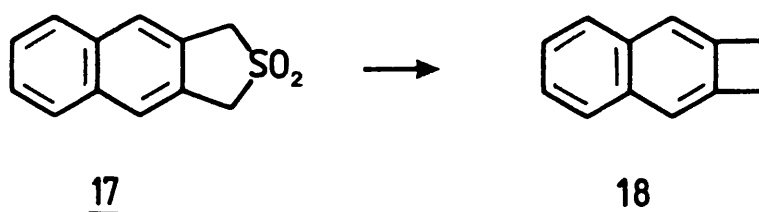
In contrast to acyclic benzylic sulphones (see Chapter 2) fused ring benzosulphones and their polycyclic analogues are unreactive on photolysis (λ= 220-280 nm) unless a further aryl group is introduced in the 1 or 3 position[8], (Scheme 3).
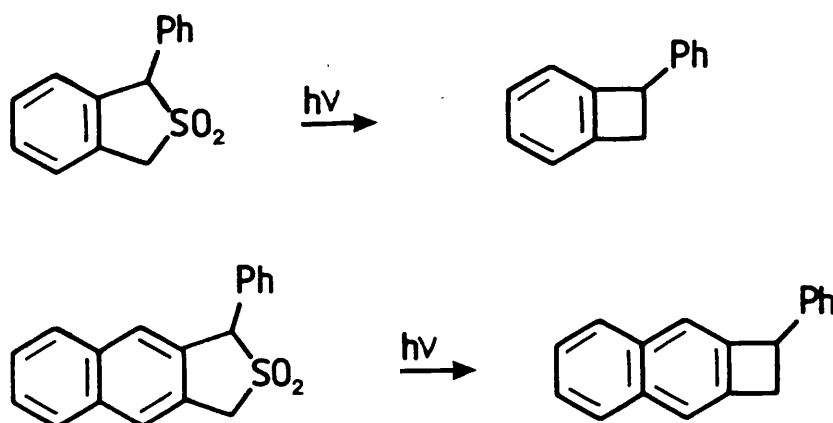
Scheme 3

Under identical conditions, 1,3-dihydrobenzo[c]thiophene 1,1-dioxide and its naphtho analogue do not react. This indicates an excitation energy of greater than 74 kcal./mol. Further evidence for the intermediacy of o-quinodimethanes was comparison of the photochemical behaviour of (14) with that of the pleiadene sulphones (19), which

readily lose sulphur dioxide on irradiation[8] (λ= 320 nm) to give

their o-quinodimethane pleiadene hydrocarbons, trapped as the dimers

(20).

19

a) R = CH$_2$—

b) R = H

20

a) R = CH$_2$-

b) R = H
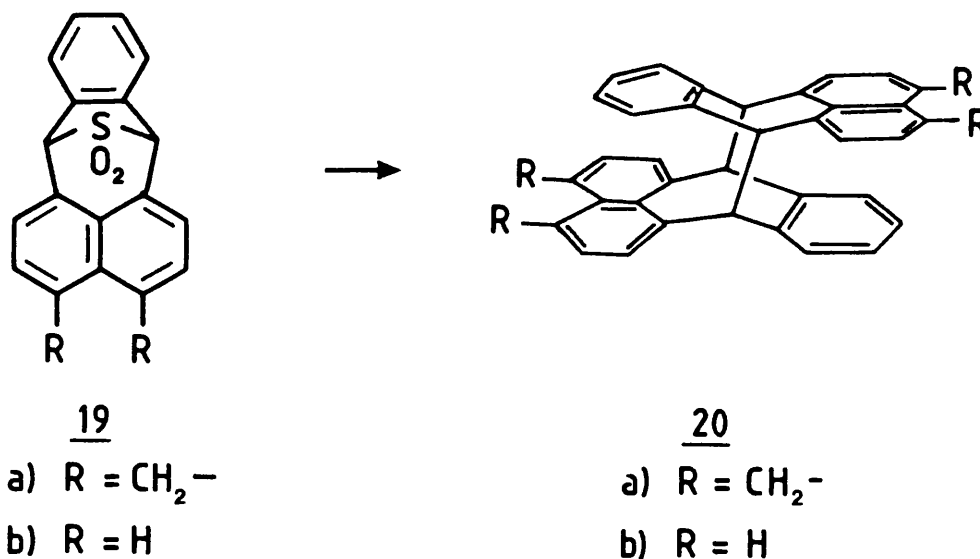
This suggests that the ease of extrusion of sulphur dioxide

photochemically corresponds to the stability of the o-quinodimethane

intermediate.

Cava et al also pyrolysed 1,3-dihydronaptho[1,2-c]thiophene 2,2-

dioxide (21)[9]. Although pyrolysis at 300° in boiling diethyl phthalate

failed to yield either the naphtho[a]cyclobutene (22) or a dimer, the

o-quinodimethane intermediate could be trapped with maleic anhydride

or N-phenyl maleimide. At 500°, gas phase pyrolysis did indeed yield

the cyclobutene.

21

22
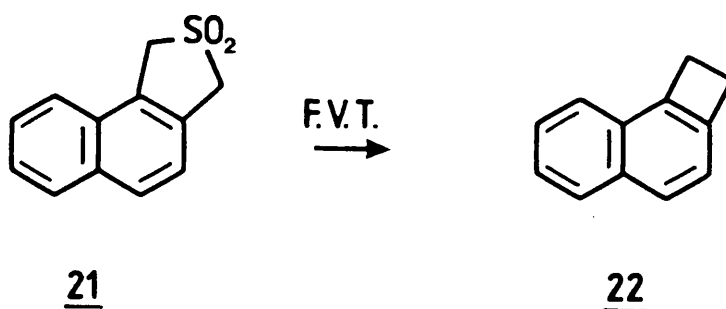
Heating (22) with maleic anhydride at 200° for 1 hour gave the
o-quinodimethane adduct (23) in 53% yield. Under the same conditions
the naphtho[b]cyclobutene (18) gave the o-quinodimethane adduct (24)
in only 2% yield (this could be increased to 61% by heating at 250°
for 1 hour)[9], (Scheme 4).

22 →

23

18 →

24
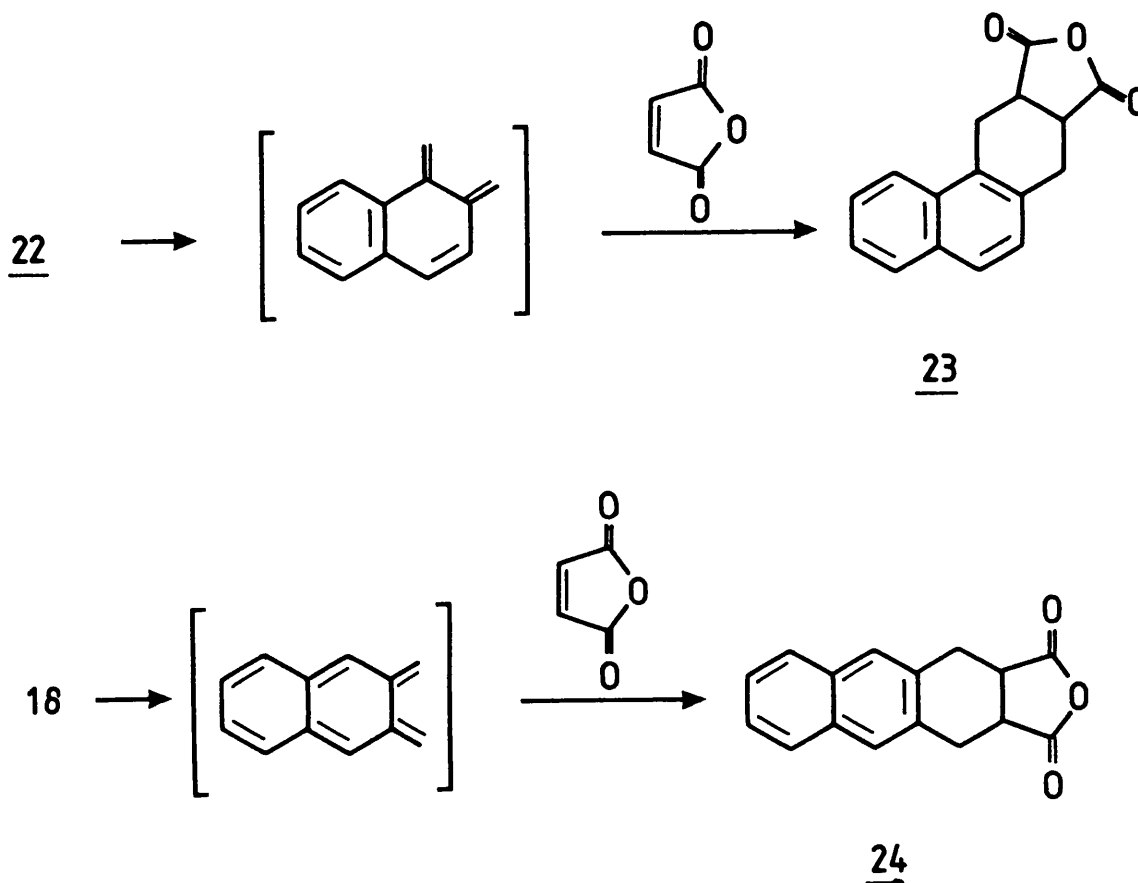
Scheme 4

The greater readiness of (22) over (18) to undergo intermolecular
cyclisation reflects the greater benzenoid character of the o-
quinodimethane intermediate.

Experimental work by Oppolzer[10] confirmed the hypothesis that these cycloaddition reactions proceed concertedly. Compound (25) gave (26) and (27) on thermolysis at 190°C. Compound (26) could then be converted cleanly into (27) in boiling o-dichlorobenzene containing traces of p-toluenesulphonic acid.
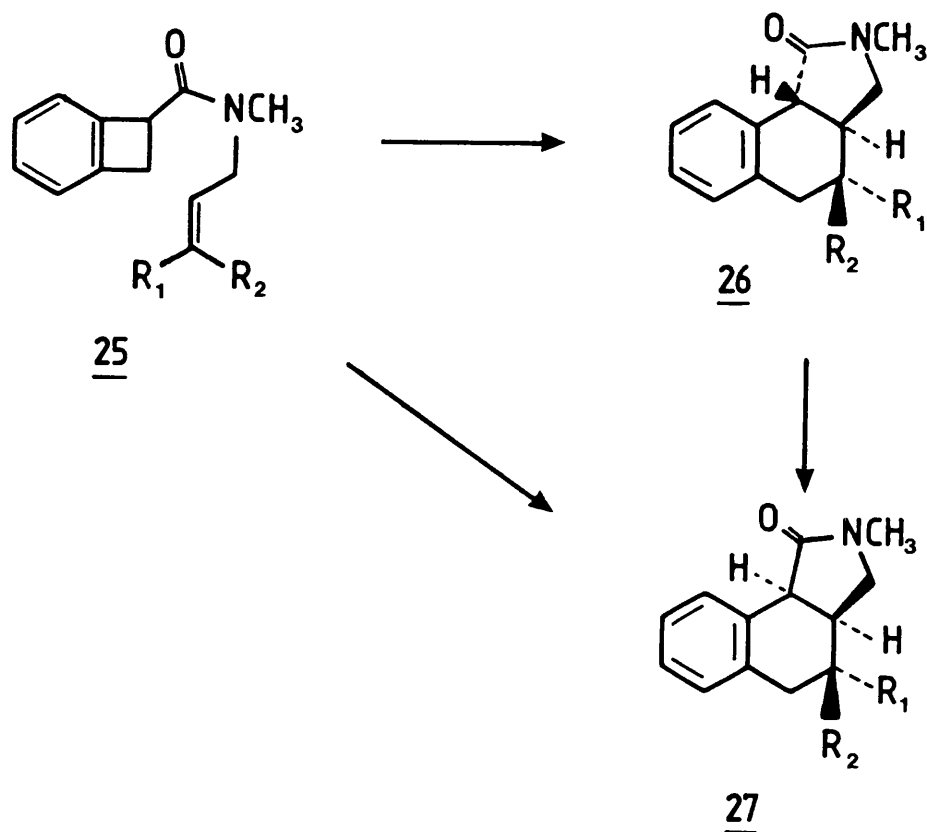
Thus there appears to be considerable stereochemical control of **3** chiral centres.

In the thermolysis of compounds of general formula (28), compounds of the structure (29) were produced. Despite extending n to 3, none of the meta-product (30) was isolated[10] (Scheme 5).
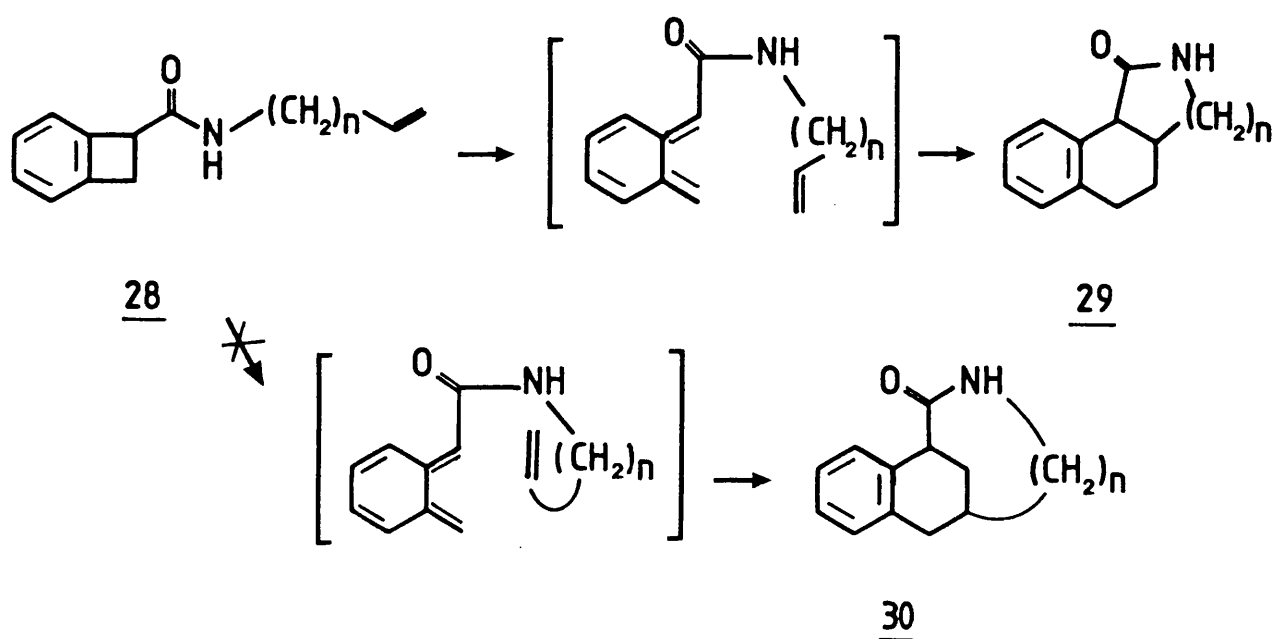
Scheme 5

In recent years benzocyclobutenes have been used in the synthesis of compounds incorporating the fused ring system of steroids. A fuller account than that related here is given in a review of Kametani and Nemoto[11]. The authors of that article were in fact in the group that were first to report the synthesis of a steroid via a benzocyclobutene[12,13] (Scheme 6).
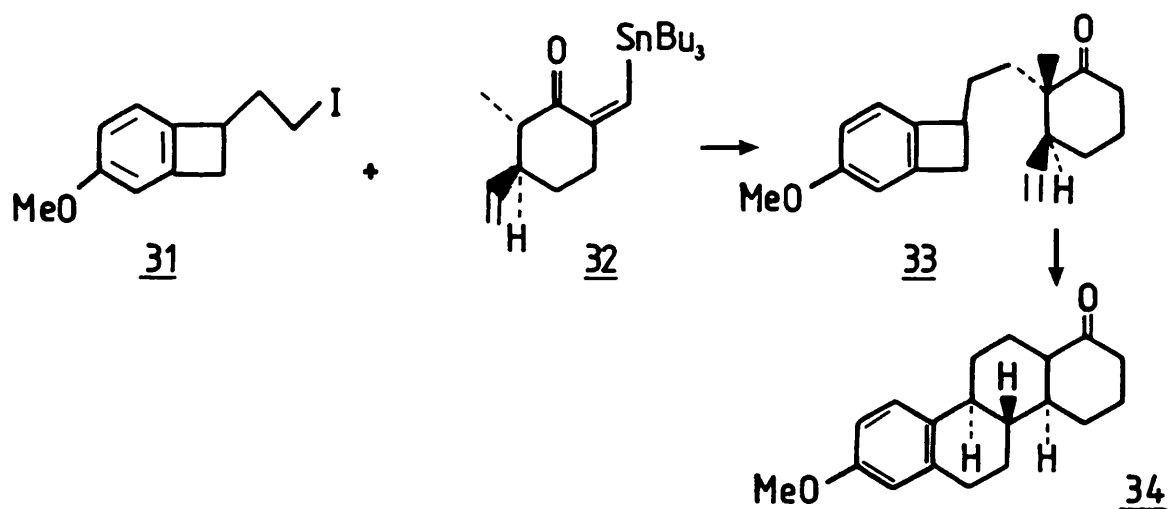
Scheme 6

Compounds (31) and (32) were synthesised in 4 and 2 stages respectively from readily available materials and o-methyl-D-homoestrone (34) was derived stereospecifically in 95% yield from the benzocyclobutene (33). The reaction is believed to proceed via the exo-transition state (35) rather than the endo-transition state (36) in order to give the correct BC ring junction stereochemistry.

35

36
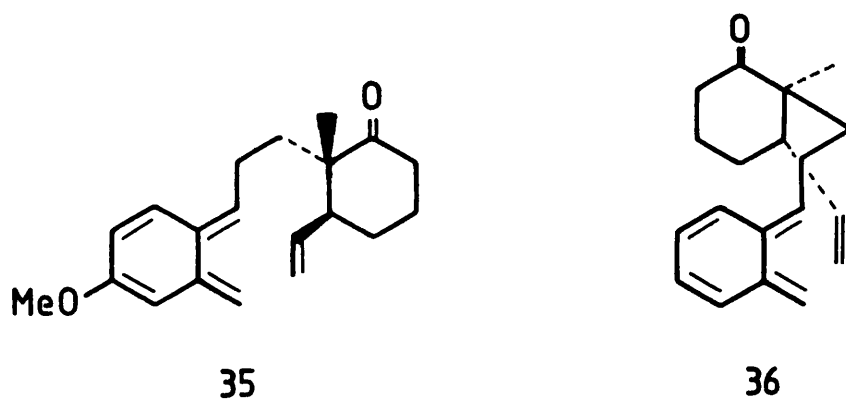
Nicholau et al[14] used (14) in the synthesis of oestra-1,3,5(10)-triene-17-one (38) (Scheme 7). The thermolysis step (37 → 38) was again accomplished in high yield (85%).

14

1) KH

2)

H₃O⁺

37

Δ

38

Scheme 7

-10-
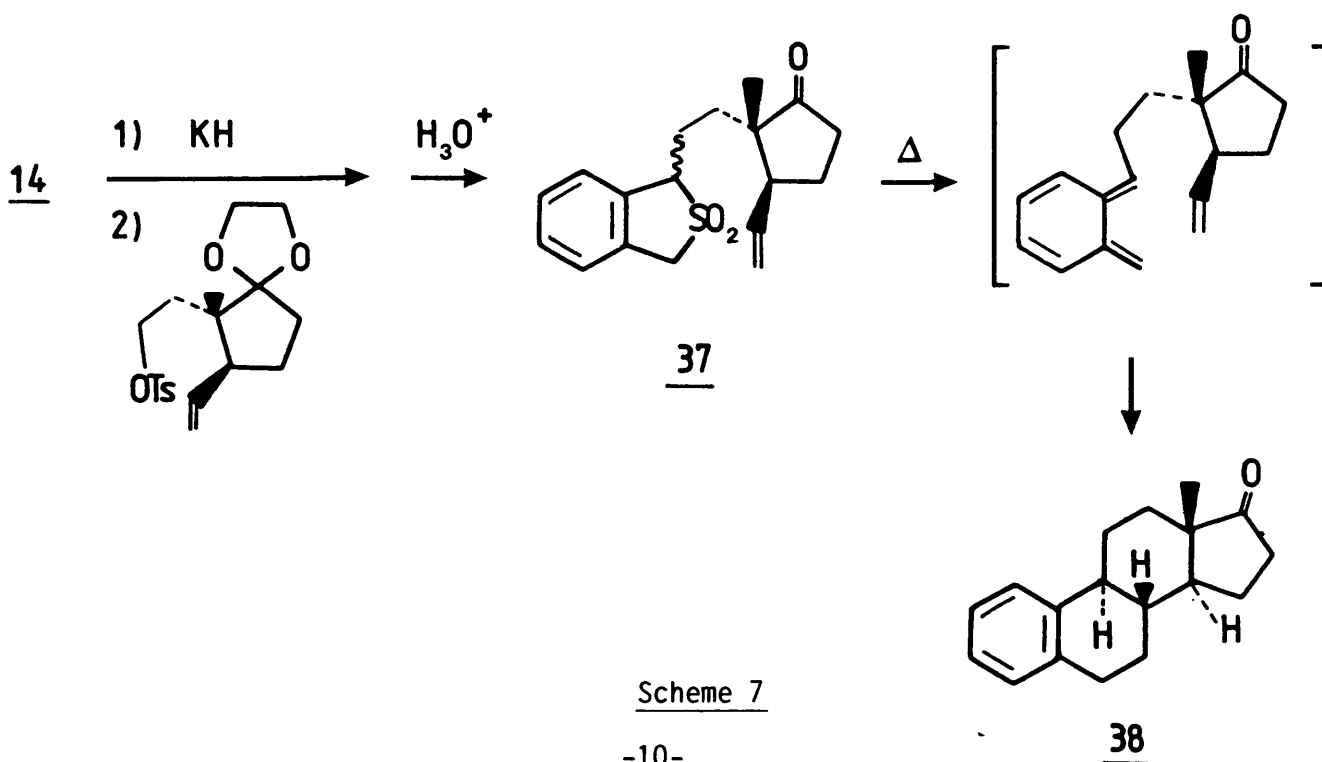
Steroids however generally include a hydroxy or methoxy substituent

at the 3-position. The first synthesis of the four fused ring system

functionalised in such a way via a benzosulphone was by Oppolzer and

Roberts[15]. Their 6 step synthesis of (±) estradiol (41) from (14)

included the thermolysis of the sulphone (39) to give stereospecifically

the steroid analogue (40).

39   **40**   **41**
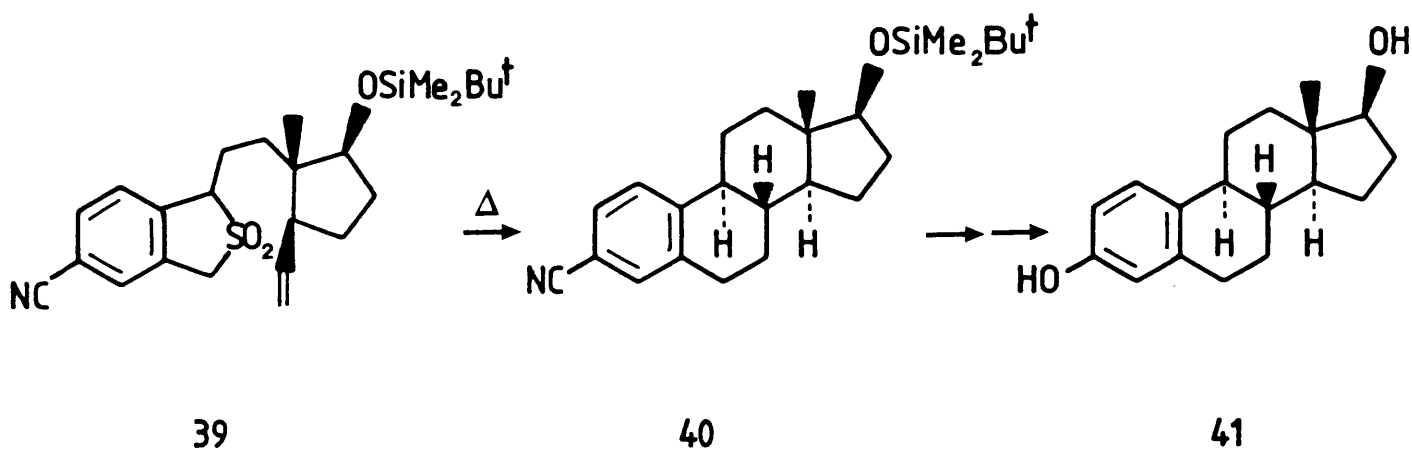
Important in such syntheses is the introduction of the appropriate

double bond containing synthon into the benzosulphone, α to the

sulphone group. This is done by treatment of the sulphone with a

powerful base and the appropriate alkylating agent. The groups of

Nicholau[14] and Oppolzer[15] have demonstrated that, in the presence of

a powerful base, 1,3-dihydrobenzothiophene 2,2-dioxides are alkylated

smoothly by alkyl iodides, bromides, tosylates and mesylates, in

yields generally in the range 60-75%.

Addition of α-sulphonyl carbanions, including α-sulphonyl Grignard

reagents, to α,β-unsaturated carbonyl systems is usually 1,2. As

such, α-sulphonyl Grignard reagents resemble conventional Grignard

reagents in their reaction with α,β-unsaturated aldehydes (Scheme 8).

EtMgBr

$\underline{p}$-MeC$_6$H$_4$SO$_2$CH$_3$ $\longrightarrow$ $\underline{p}$-MeC$_6$H$_4$SO$_2$CH$_2$MgBr

$\Big\downarrow$ CH$_3$CH=CHCHO

$\underline{p}$-MeC$_6$H$_4$SO$_2$CH=CHCH=CHCH$_3$ $\xleftarrow{\text{H}_3\text{PO}_4}$ $\underline{p}$-MeC$_6$H$_4$SO$_2$CH$_2$CHOHCH=CHCH$_3$
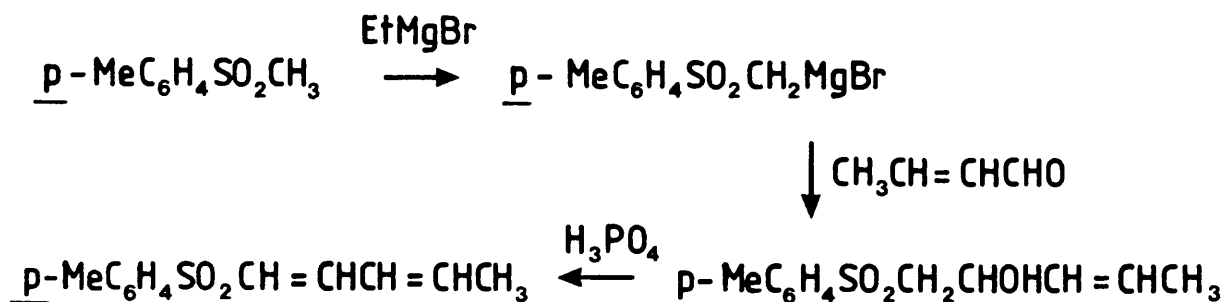
Scheme 8

The two diverge however in their reactions with α,β-unsaturated ketones. Grignard reagents such as ethyl magnesium bromide give a mixture of 1,4- and 1,2-addition, eg, with 4-phenyl-3-buten-2-one[17]. For α-sulphonyl Grignard reagents 1,2-addition continues to predominate; for example, $\underline{p}$-tolylsulphonylmethylmagnesium bromide gave a 67% yield of the 1,2-addition product with trans-4-phenyl-3-buten-2-one whilst giving no 1,4-addition[16] (Scheme 9). Dehydration gave (42) rather than (43).

$$\underset{\text{OH}}{\underset{|}{\underline{p}\text{MeC}_6\text{H}_4\text{SO}_2\text{CH}_2}}\overset{\overset{\text{CH}_3}{|}}{\text{C}}-\text{CH=CHPh}$$

$$\underline{p}\text{MeC}_6\text{H}_4\text{SO}_2\text{CH}_2\text{MgBr}$$

$$\underset{\text{OH}}{\underset{\text{Ph}\quad\quad\text{O}}{\underline{p}\text{MeC}_6\text{H}_4\text{SO}_2\text{CH}_2-\text{CH}-\text{CH}_2\text{CCH}_3}}$$

$$\underline{p}\text{MeC}_6\text{H}_4\text{SO}_2\text{CH}=\overset{\overset{\text{CH}_3}{|}}{\text{C}}-\text{CH=CHPh}$$

42

$$\underline{p}\text{MeC}_6\text{H}_4\text{SO}_2\text{CH}_2-\overset{\overset{\text{CH}_2}{\|}}{\text{C}}-\text{CH=CHPh}$$

43
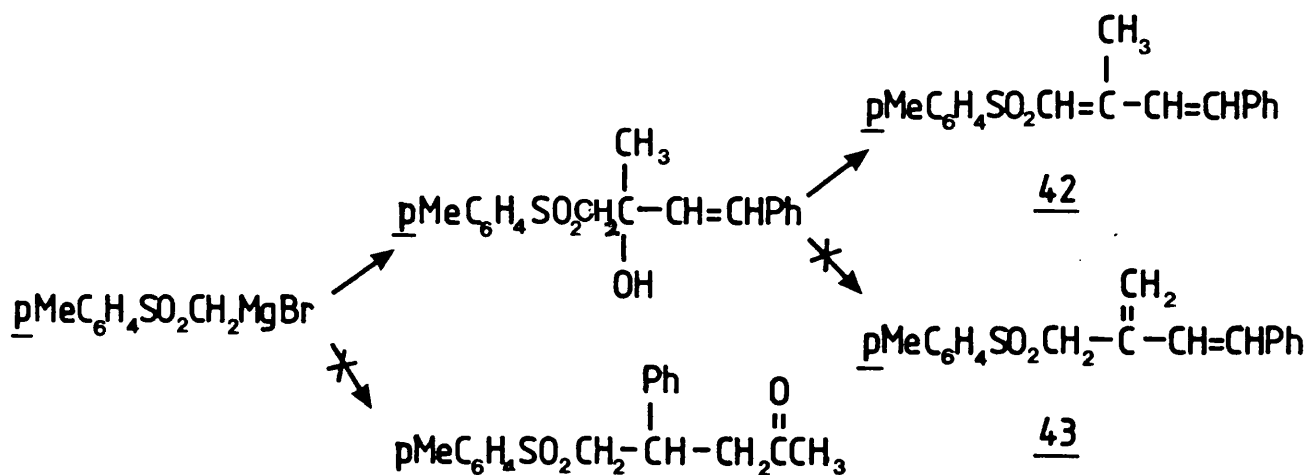
Scheme 9

1,4- Addition of α-sulphonyl carbanions is rare and the products may undergo further reaction. Reaction of an allylic α-sulphonyl

carbanion with an α,β-unsaturated ester gives the 1,4-adduct which

however is not generally isolable but instead reacts further to

give the cyclopropylsystem. This has been exploited by Martel[18]

and Crombie et al[19] to synthesise ethyl   chrysanthemate (44)

(Scheme 11) and presqualene alcohol (45) respectively (Scheme 10).

44

45

Scheme 10

-13-

Condensation of benzyl sulphonyl α-carbanions with α,β-unsaturated carbonyl compounds has received no significant attention.

Divinyl ketone has been employed for attempted Michael additions but without success. Bisalkylation has been the usual reported result[20,21], leading to spiro-systems where the second step is intramolecular[20]. The explanation for bisalkylation is the probable greater electrophilicity of the alkyl vinyl ketone over divinyl ketone[22].

β-chloroethyl vinyl ketone (46) has been used as a divinyl ketone equivalent[22] (Scheme 11).

46
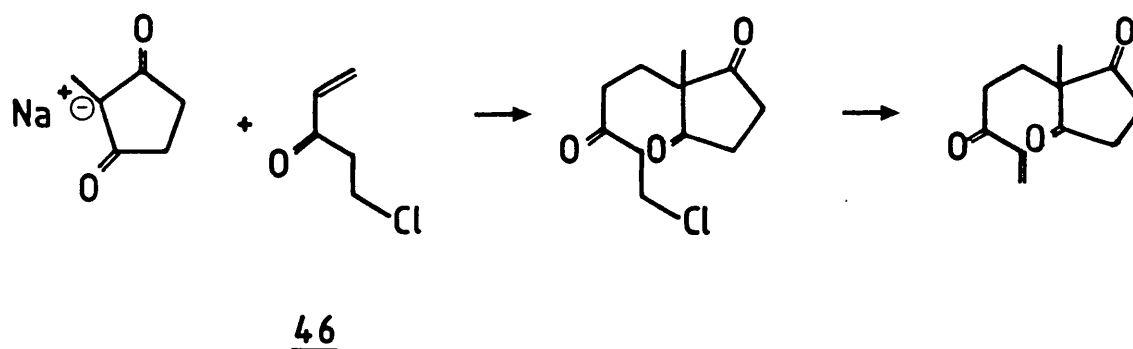
Scheme 11

It was envisaged that if compounds (47) and (48) could be prepared, these would give, on pyrolysis, compounds (49) and (50) and thus constitute syntheses of steroid ring systems. Should these be accomplished then such syntheses would involve fewer steps than those employed by the groups of Nicholau[14] and Oppolzer[15].

-14-
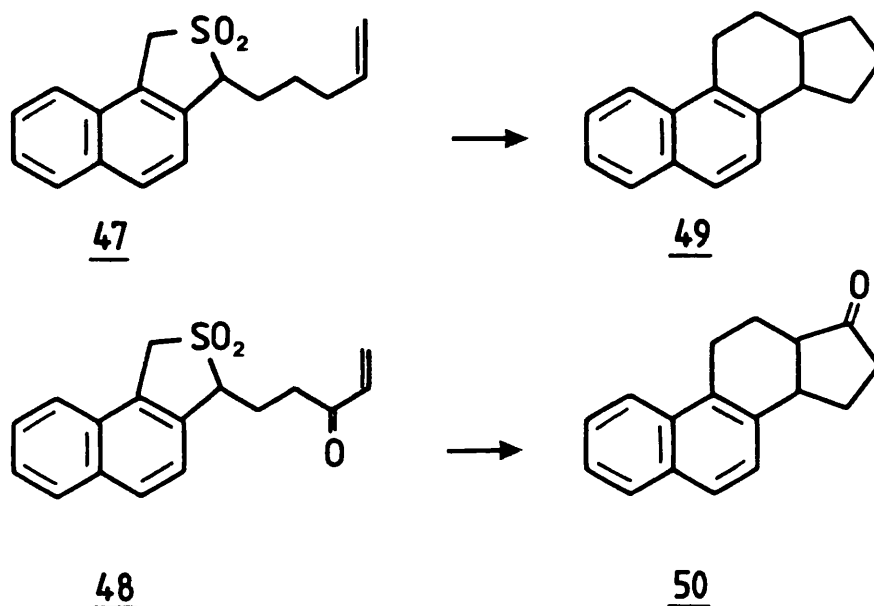
Using (21) as a starting material, divinyl ketone or a divinyl
ketone equivalent would be required for the preparation of (50).

However, compound (17) was to be employed initially to investigate
the alkylation and pyrolysis steps because of the greater cost and
possible mixed alkylation products of the naphtho [1,2-c]sulphone.

1.2 Correlation Between Thermal, Photochemical and Mass Spectral Processes

Comparison of the mass spectral breakdown of a compound with its
behaviour on thermolysis or photolysis is often made because for many
compounds the fragmentations are observed to coincide. Examples have
been published[23] and the reader is referred to these for further
reading. The correlation for sulphones has not been thoroughly
studied, although examples have again been published. For example
Fields and Meyerson found that the major thermolysis product of
dibenzothiophene 1,1-dioxide (51) was dibenzofuran (52), not biphenylene,

-15-

and study of its mass spectrum showed that (52) was also the product under electron impact[24].

$$\underline{51} \longrightarrow \underline{52}$$
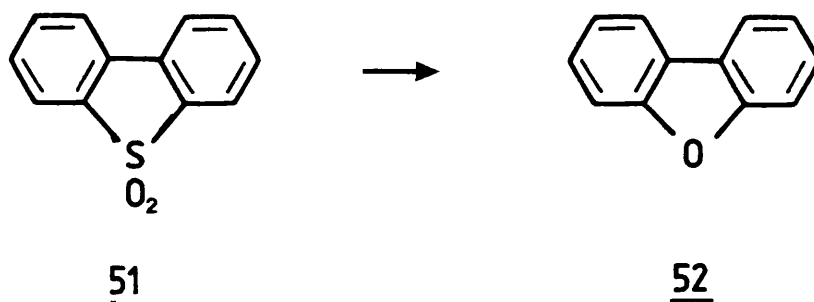
However, many fragmentations in the mass spectrometer do not correspond to observed thermal and photochemical processes. Thermolysis of **4-t-butyl-o-phenylene sulphite(53)** gives dimers of t-butylcyclopenta-dienone (54) as a result of loss of carbon monoxide and sulphur monoxide. In the mass spectrum however the base peak corresponds to the $[M-CH_3]^+$ ion[25]. It is suggested by way of explanation that this ion is stabilised by a p-oxonium ion (55) .

$$\underline{53} \quad \xrightarrow{\Delta} \quad \underline{54}$$

$$\text{M. S.}$$

$$\underline{55}$$
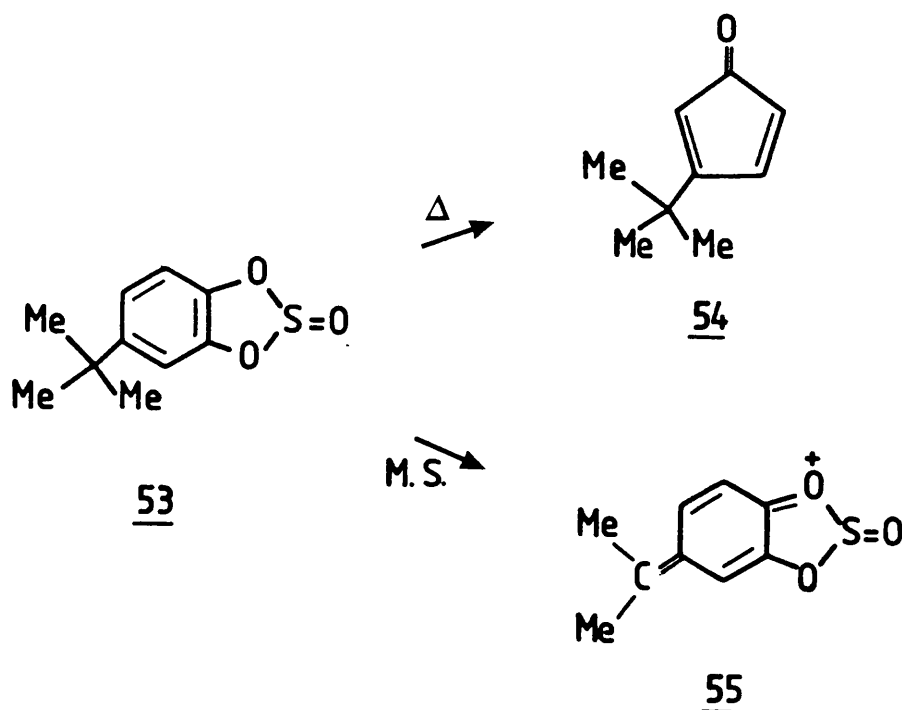
The reasons for the differences between mass spectral and pyrolysis behaviours are not difficult to identify. A mass spectrum involves ionic processes which often have lower activation energies than their neutral thermal and photochemical counterparts. There is also usually far more energy available in a mass spectrometer than in a thermal or photochemical reaction; a 3ev activation energy is known to correspond to a thermolysis at 800°C or a photolysis at 400 nm[26]. Thus the processes normally observed in a mass spectrometer are far less selective than thermal or photochemical reactions, and only the most intense peaks should be considered in any correlation studies.

In a 'Mass Spectral Studies' section in this chapter and in other chapters a study will be made comparing mass spectra with thermal and photochemical reactions in an attempt to identify common processes.

1.3 Preparation of Substituted 1,3-Dihydronaphtho[2,3-c]Thiophene 2,2-Dioxides

Treatment of 1,3-dihydronaphtho[2,3-c]thiophene 2,2-dioxide (17) with n-butyl-lithium followed by an excess of alkyl halide gave, in the case of both compounds(57a) and (57b) a 59% yield of the alkylated derivative, which is in the general range of yields expected for the alkylation of benzosulphones[14,15] (Table 1.1).

$\underline{17}$ $\xrightarrow{\text{n-BuLi}}$ $\underline{56}$ $\xrightarrow{\text{R-X}}$ $\underline{57}$

a) R = Me

b) R = $(CH_2)_3CH = CH_2$

Table 1.1:- Preparation of Substituted 1,3-Dihydronaphtho
[2,3-c]Thiophene 2,2-Dioxides

Alkyl Halide	Product	mp°C	Yield %
MeI	57a	198-200	59
H₂C=CH(CH₂)₂CH₂Br	57b	110-111	59

Attempts to react (56) with divinyl ketone or β-chloroethyl vinyl ketone were considerably less successful. Addition of a slight excess of either of these two electrophiles always led to the recovery of some of the starting material (50-65% recovery) along with white solids which were polymeric in character. No divinyl ketone or β-chloroethyl vinyl ketone was ever recovered.

1.4 Preparation of 1,5-Dihalopropan-3-one Ketals

Since compound (61) could not be prepared from (17) using either divinylketone or β-chloroethyl vinyl ketone, the 1,5-dihalo ketals (58) and (59) were prepared, in order to act as divinyl ketone equivalents and make possible the synthesis of (61) <u>via</u> the naphtho-sulphonyl ketal (60).

17 $\xrightarrow[\text{2) (59)/(60)}]{\text{1) n - BuLi}}$

60

61

X = Cl, I
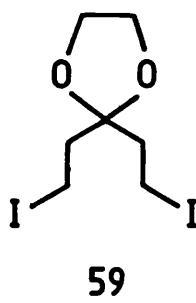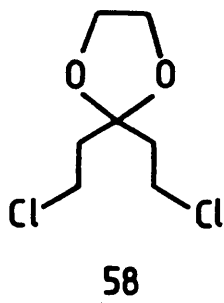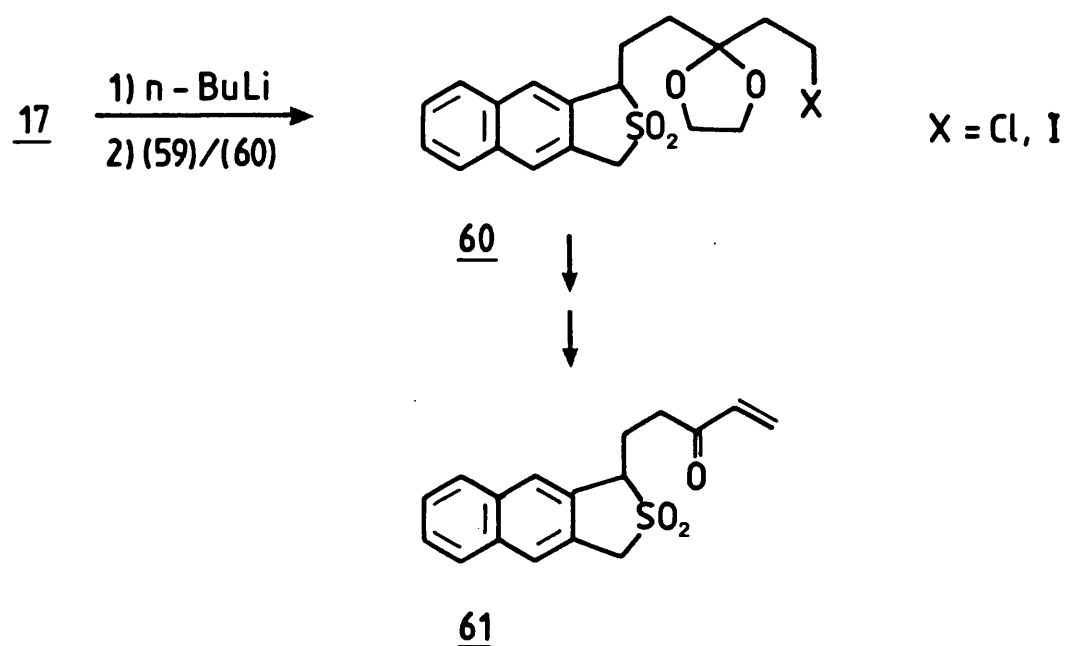
Compounds (58) and (59) were prepared from the appropriate ketones. 1,5-Diiodopentan-3-one is itself a compound not previously reported and was prepared in 72% yield from 1,5-dichloropentan-3-one by the Finkelstein reaction.

1.5 Attempted Preparation of (60)

Attempts to react (56) with (58) or (59) were unsuccessful, starting materials being the only identifiable compounds recovered. While for the

dichloro-electrophile this can be explained in terms of the unreactivity

of alkyl chlorides no such explanation is possible for the diiodide.

The successful preparation of (57a)   using methyl iodide

suggested that the alkylation should have been straightforward.

To investigate the possibility that rather than condensation between

(56) and (59) proton transfer was occurring instead, the reaction was

quenched with deuterium oxide. However work up and chromatography

gave the 1,5-diiodopropan-3-one ketal and a mixture of the undeuterated,

the monodeuterated and dideuterated sulphones, where the undeuterated

and dideuterated compounds were present in approximately equal amounts;

thus it seems unlikely that proton transfer is occurring, and the

author is unable to explain the non-reactivity of the carbanion (56)

with the diiodide (59).

1.6   Photolysis and Thermolysis of 1-(Pent-4-enyl)-1,3-dihydro-naphtho[2,3-c]thiophene 2,2-dioxide (57b)

Irradiation of (57b) at 254 nm in methanol gave, after 21 hours, a

quantitative recovery of starting material.

Heating under reflux a solution of (57b) in 1,2,4-trichlorobenzene

(b.p. 213°C) also gave a quantitative recovery of starting material.

However thermolysis at 300°C in boiling diethyl phthalate produced

the cyclopentatetrahydroanthracene (62), along with some of (63)

57b → **62** + **63**
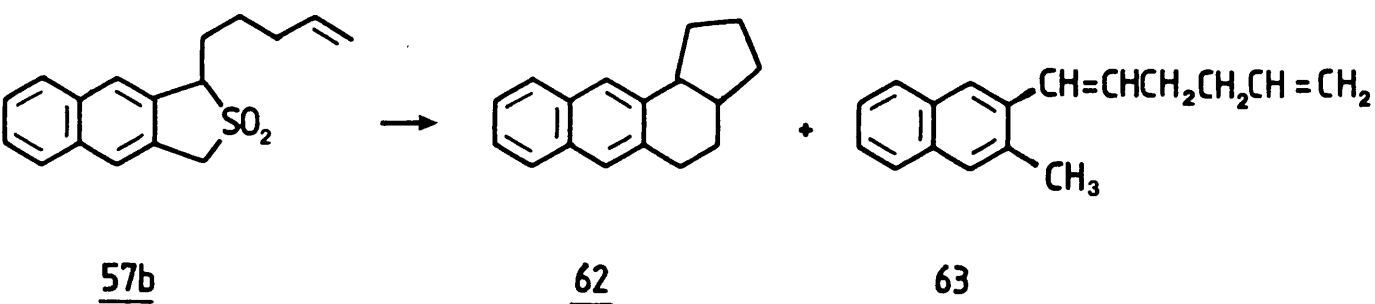
Compound (62), the product of an intramolecular Diels-Alder cyclisation and compound (63), the product of a [1,5] hydrogen shift, were in the ratio 88:12 respectively.

The conditions required for the pyrolysis are consistent with the work of Cava et al[6,7] as discussed in the Introduction. Oppolzer and Roberts successfully thermolysed a series of benzosulphones in boiling 1,2,4-trichlorobenzene[15] and it should be noted that a higher temperature was necessary for the thermolysis of this naphtho [2,3-c] sulphone. This can be explained in terms of the fact that the intermediate o-quinodimethane generated from (57b) would involve localisation of all the double bonds; although resonance energies have not been determined for benzo and naphtho sulphones, the difference between the two would probably not be dissimilar to that between benzene and naphthalene, namely 25 kcal mol^{-1},[27].

1.7   Preparation of Deuterated 1,3-Dihydronaphtho[1,2-c]Thiophene 2,2-Dioxide

Treatment of (21) with one equivalent of n-butyl-lithium at -78°C gave rise to a mixture of anions (64) and (65), which were quenched with deuterium oxide.

$21 \longrightarrow$ **64** + **65**
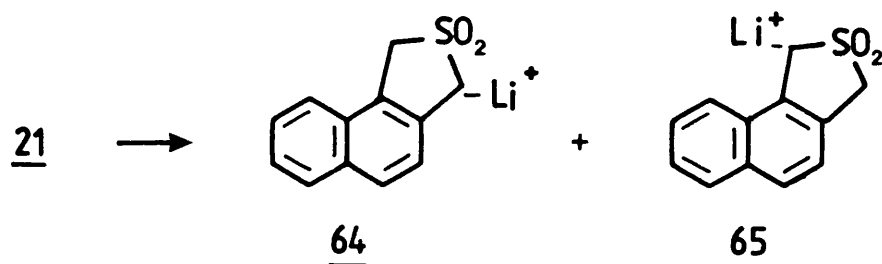
The 'H n.m.r. spectrum of (21) shows two singlets at δ(CDCl$_3$) 4.67, 4.53, which have not as yet been attributed to specific benzylic positions. Deuteration of the mixture of (64) and (65) led to a slightly greater reduction of the integration of the higher field signal, but there appeared to be no significant preference of one carbanion over the other.

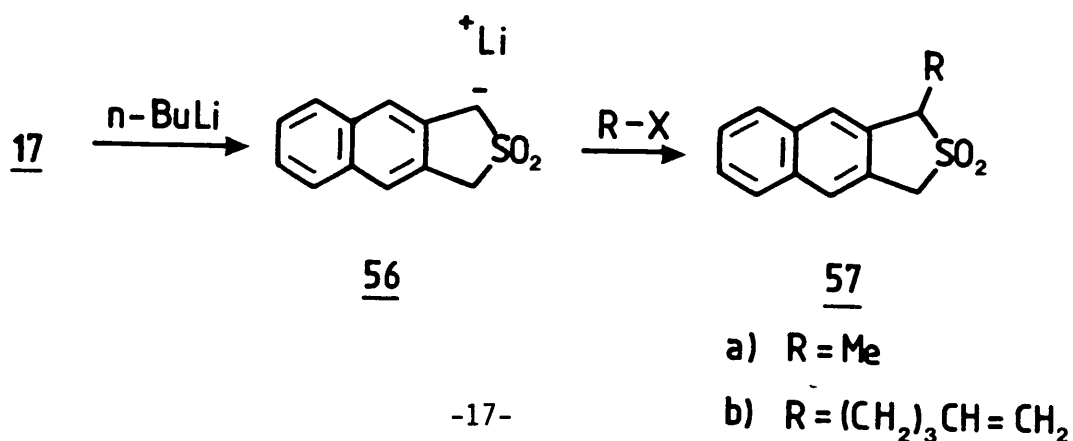## 1.8 Preparation of Substituted 1,3-Dihydronaphtho[1,2-c]Thiophene 2,2-Dioxides

Alkylation of (21) using the same conditions as for the preparation of (57b) gave a mixture of substituted naphthosulphones (66a) and (67a) in poor yield.

$21 \quad \xrightarrow[\text{ii) RBr}]{\text{i) BuLi}} \quad$ **66** + **67**
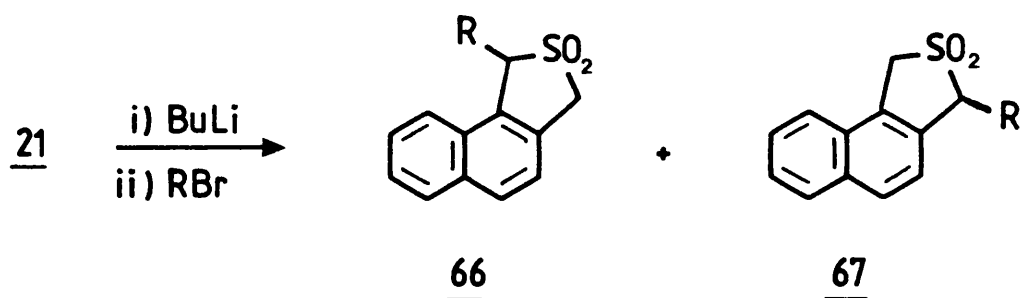
a) $R = (CH_2)_3 CH = CH_2$
b) $R = CH_2 Ph$

Using lithium diisopropylamine (LDA) as base instead of n-butyl-lithium resulted in a slight increase in the yield; however the

introduction of hexamethylphosphoric triamide (HMPT) into the solution

of (21) in tetrahydrofuran (THF) before the addition of LDA produced

a very large increase in the yield, giving a nearly quantitative

recovery of substituted naphthosulphones. These results are summarised

in Table 1.2.

Table 1.2:- Alkylation of 1,3-Dihydronaphtho[1,2-c]Thiophene 2,2-Dioxide
            (21) with 5-Bromopent-1-ene

Base	Additional Reagent	Yield (%)
n-Buhi	-	25
LDA	-	37
LDA	HMPT	84

It would seem likely that the HMPT was able to complex the lithium

cation and thereby increase the nucleophilicity of the sulphonyl

carbanion. Indeed the complex between HMPT and lithium bromide has

been isolated and characterised[28]. Doolittle studied the reaction of

alkynyl anions with oxiranes in THF and found a dramatic increase in

the yield of the acetylenic alcohol when HMPT was present in the

reaction mixture[29]. Other complexing reagents were tried and were

also found to increase the nucleophilicity of the alkynyl anion,

although only N,N,N',N'-tetramethylethylenediamine was found to be as

effective as HMPT. HMPT has also been used as a co-solvent in the

Wittig reaction, where it gives a high proportion of cis-olefins[30],

and its use was recently reported in the intramolecular condensation

of a sulphonyl carbanion with an epoxy group[31].

Clearly the yield of (66a) and (67a) is much lower than that of
(57b) when the alkylation is performed under similar conditions. A
possible explanation for this is the greater double bond character of
the naphtho [1,2] bond compared to the naphtho [2,3] bond. Crumbie
and Ridley have shown that the α-sulphonyl carbanion of 2,5-
dihydrothiophene 1,1-dioxide tends to undergo decomposition to ring
opened compounds[32] (Scheme 12).
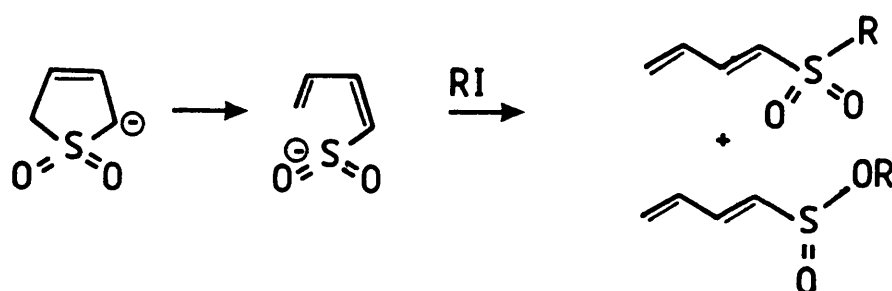
Scheme 12

Therefore it is possible that a similar ring opening (even through
the double bond is part of an aromatic system) would reduce the yield
of (66a) and (67a).

Treatment of (21) with n-butyl-lithium followed by an excess of
benzyl bromide also gave a mixture of alkylation products, in this
case (66b) and (67b).

1.9 Isomer Ratios of Substituted 1,3-Dihydronaphtho[1,2]Thiophene 2,2-Dioxides

In the mixture of (66b) and (67b), partial purification has allowed
the n.m.r. spectrum of one of the isomers to be defined. Although
this spectrum cannot be assigned to either of the two structures,

(66b) or (67b), it does allow the ratio of isomers in the original mixture to be calculated.

As previously stated in 1.7, the n.m.r. spectrum of (21) shows two singlets at $\delta(CDCl_3)$ 4.67 and $\delta(CDCl_3)$ 4.53 which have not been attributed to either of the two pairs of benzylic hydrogens. The mixture of (66a) and (67a) shows, amongst others, two distinct multiplets at $\delta(CDCl_3)$ 4.80-4.56 and $\delta(CDCl_3)$ 4.53-4.20. If one multiplet is assigned to all signals originating from hydrogens bonded to the benzylic carbon in the '1' position and the other multiplet is assigned to all those in the '3' position, a ratio of isomers can be calculated and is included in Table 1.3. However such assignments are presumptious and may be incorrect. Interestingly the ratio of isomers changed when HMPT was introduced into the reaction mixture.

Table 1.3:- The Ratio of Isomers in Mixtures of Substituted
1,3-Dihydronaphtho[1,2-c]Thiophene 2,2-Dioxides

Electrophile	Ratio
D_2O	52:48
$CH_2=CH(CH_2)_2CH_2Br$	65:35
$CH_2=CH(CH_2)_2CH_2Br$, with HMPT	54:46
$C_6H_5CH_2Br$	62:38

1.10 Attempted Separation of Substituted 1,3-Dihydronaphtho[1,2-c]-
Thiophene 2,2-Dioxide Isomers

Attempts were made to separate the mixtures of (66a)/(67a) and (66b)/(67b) into their individual components using column chromatography.

These were generally unsuccessful, leading usually to a variation in concentration of the two isomers across a range of fractions. In the case of (66b)/(67b) this did give some clarification of the n.m.r. spectrum of the initial mixture and enabled calculation of the ratio given in Table 1.3.

In an attempted separation of (66a) and (67a), silica gel impregnated with silver nitrate was used. This is a technique first reported by De Vries[33] and well documented in the literature[34]. However, in this particular case no improvement in purification was shown over ordinary silica gel or alumina.

1.11   Thermolysis of a Mixture of 1,3-Dihydro 1-(pent-4-enyl)naphtho-
        [1,2-c]Thiophene 2,2-Dioxide (67a) and its 3-(Pent-4-enyl)
        Isomer (66a)

Thermolysis of a mixture of (66a) and (67a) was accomplished under the conditions used for (57b); a lower temperature would probably have sufficed but a shortage of material did not allow for experimental divergence. The products were a mixture of (68) and (69) and a mixture of what were presumed to be the styrenes (70) and (71). The mixture of (68) and (69) could only be identified as two compounds by gas-liquid chromatography, and was not found to be separable into its two components.

66a
+
67a

→

68

+

69

CH₃

+

70

71
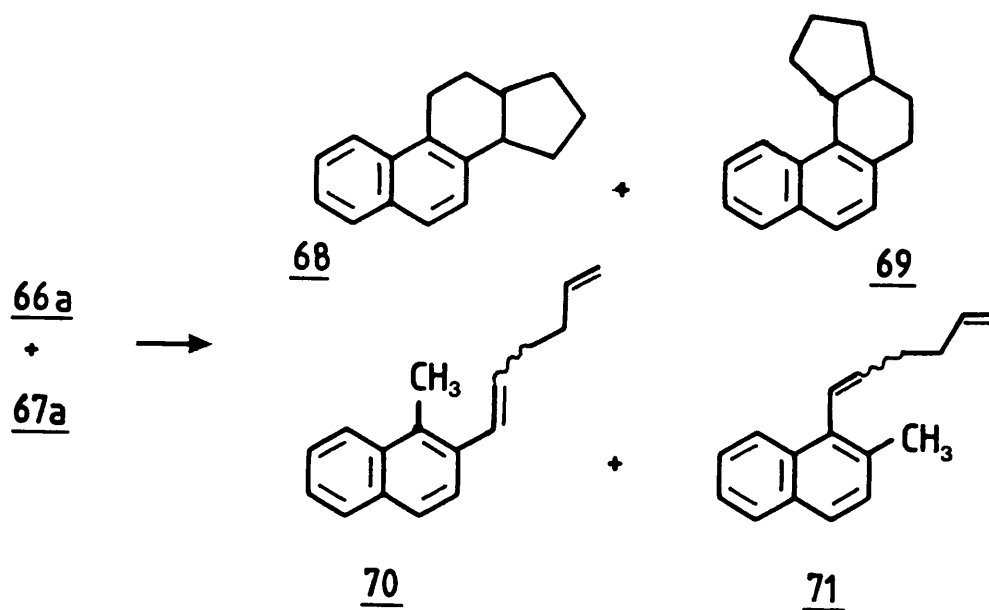
1.12 Mass Spectral Studies

The mass spectrum of (57b) (Figure1.1) shows the base peak to be 222, representing loss of SO_2. At 22ev this process is even more dominant, with other peaks representing less than 10% of the base peak, the only exception being the molecular ion m/e 286 (59%).

SO₂

57b
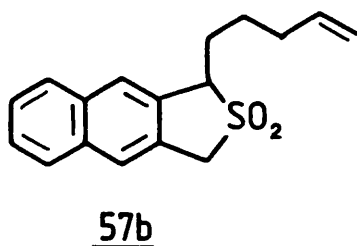
The ions at m/e 179 and 181 are generated by loss of C_3H_5· and C_3H_7· respectively from ion m/e 222, rather than by loss of much larger fragment from the molecular ion. Evidence for this comes from the presence of metastable peaks at m/e 144 and 147. The processes giving rise to ions m/e 165-168 are rather less clear. Possibly ions m/e 166 and 165 have in turn been derived from ions m/e 181 and 179 respectively; both steps would be expected to give a metastable peak

at m/e 152, which is indeed present. The metastable peaks expected if they had been derived from ion m/e 222 are absent.

The behaviour of (57b) in a mass spectrometer can be seen, therefore, to correspond with its behaviour on thermolysis, with loss of 'SO$_2$' predominating in both. Dougherty has suggested that a spectrum showing few or small metastable peaks will correspond to the photochemistry of a compound, while the occurrence of large metastable peaks in a spectrum will indicate how the compound will behave on thermolysis[35]. However, this is not backed up by the spectrum of (57b). The dominant mass spectral process of (57b), loss of SO$_2$, was observed on thermolysis at 300°C, but not at all on photolysis at 254 nm. This is despite the fact that the mass spectrum contained only a few small metastable peaks.

The mass spectrum of (62) (Figure 1.2) shows many similarities to that of its sulphone precursor, with peaks at m/e 165, 166, 179, 181 and 222. That is not to say however that those peaks are derived by common processes since there is no reason to presume that (62), or its positively charged analogue, is formed during the electron bombardment of (57b). The ions observed are present in different proportions and Figure 1.2 shows two ions not previously seen in Figure 1.1, m/e 193 and 194. However, both the mass spectra involve the generation of similar submolecular fragments, which must therefore have relatively high degrees of stability associated with them. Indeed, to lose what is presumably an allyl radical C$_3$H$_5$· (giving the common ion m/e 181) (62) may need to first under go a reverse Diels-Alder reaction in

order to generate the necessary terminal double bond.
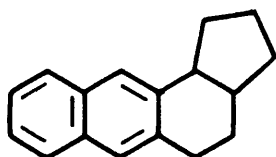
62

The mass spectrum of a mixture (66a) and (67a) shows, not surprisingly, close similarities to that of (57b). The only difference worthy of mention is that the ions m/e 222 are less dominant, indeed at 30ev the molecular ions form the base peak and by quite a large margin, the combined occurrence of these ions being five times that of ions m/e 222.

FIGURE 1.1

Mass spectrum of (57b) at 70 eV.
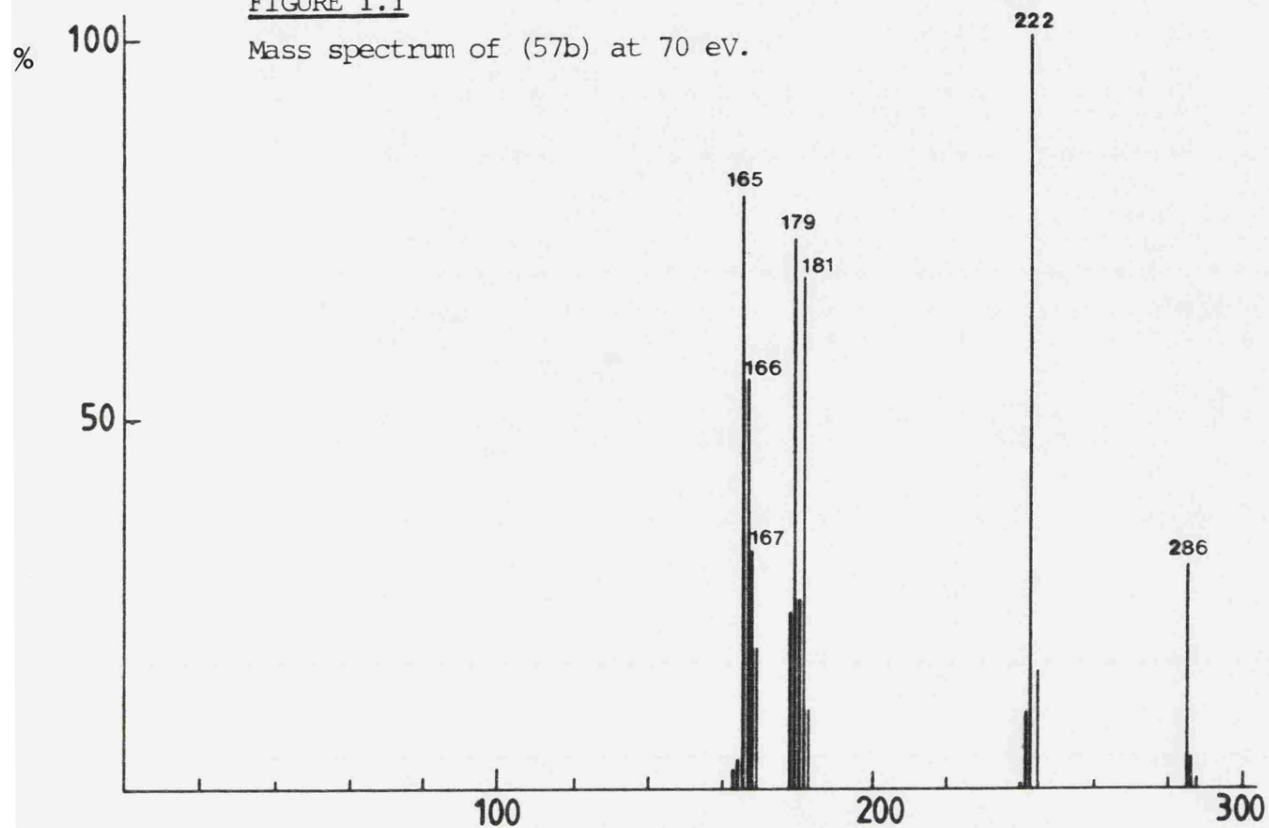
FIGURE 1.2

Mass spectrum of (62) at 70 eV.
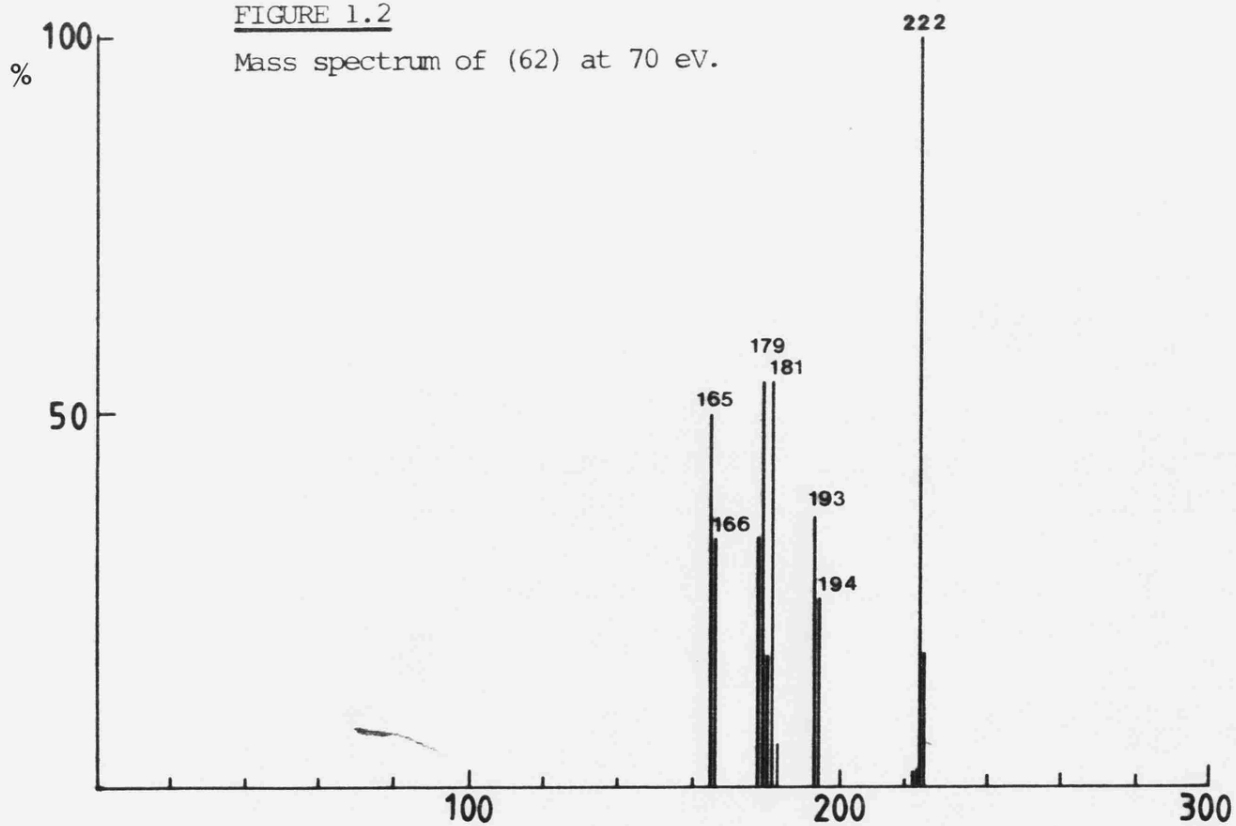
CHAPTER TWO

PREPARATION AND PYROLYSIS OF 2-PHENYLTHIETAN 1,1-DIOXIDES

2.1 Introduction

Whereas the extrusion of sulphur dioxide from benzo- and naphtho-
derivatives involves o-quinodimethane intermediates, non-cyclic benzylic
sulphones can only lose sulphur dioxide via a different mechanism.
Leonard found that flash vacuum thermolysis of dibenzyl sulphones
gives dibenzyls[36] (Scheme 13).

$$R-CH_2-SO_2-CH_2-R \xrightarrow{600-700^\circ C} 2\left[R-\dot{C}H_2\right] \downarrow$$

$$R-CH_2-CH_2-R$$
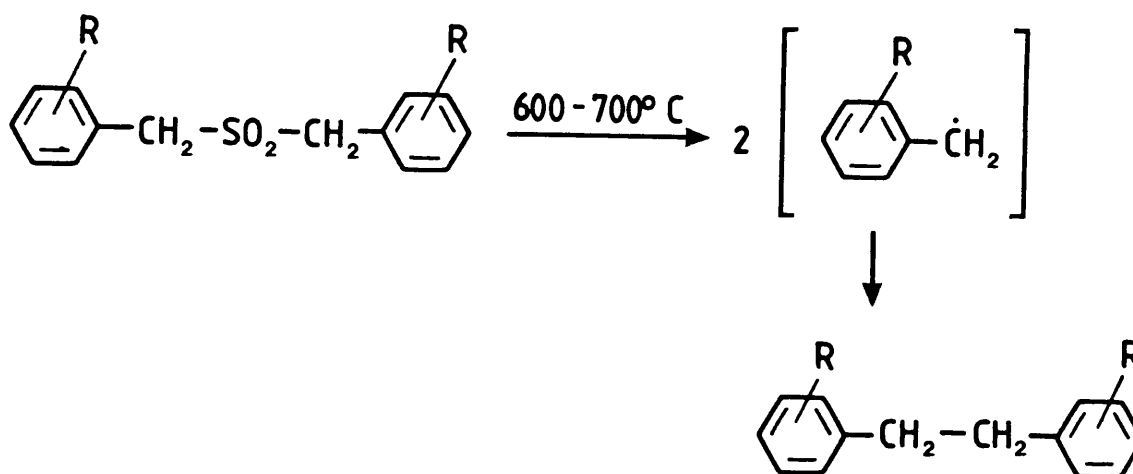
Scheme 13

He proposed that the reaction occurs via the homolytic fission of
the sulphur-carbon bonds to give benzyl radicals, which then couple.
This type of reaction was exploited by Staab and Haenel in the
synthesis of cyclophanes[37]. Vapour phase thermolysis at 500°C and
0.1 mm/Hg of sulphones (72) and (73) gave [2,2](4,4')biphenylophane
(74) and 5,6,17,18-tetrahydro[2,2] (2,7) phenanthrenophane (75)
respectively.

72 → 74

73 → 75
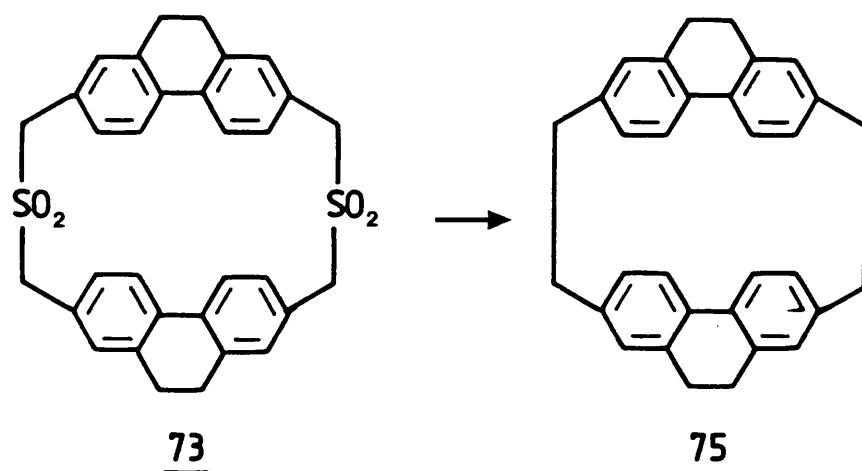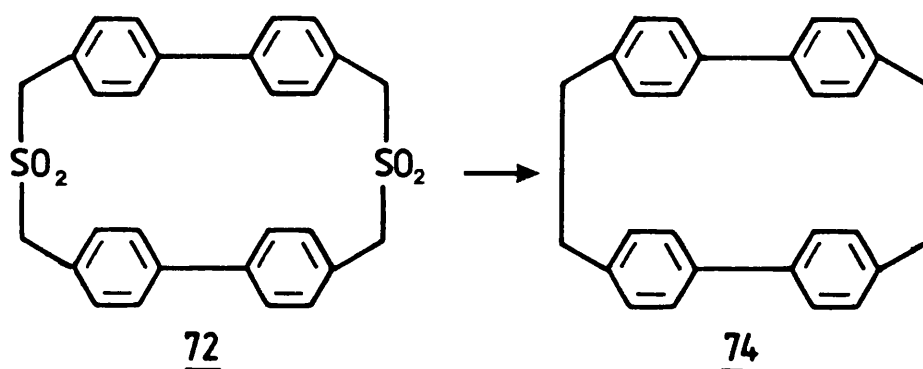
The extrusion of two sulphur dioxide molecules from bis-sulphones
need not be simultaneous. For example Sherrod et al found that in
the flash vacuum thermolysis of the bis-sulphone (76), the monosulphone
(77) could be isolated as well as the cyclophane (78)[38].

76   500°C / 15mm/Hg   77   +   78
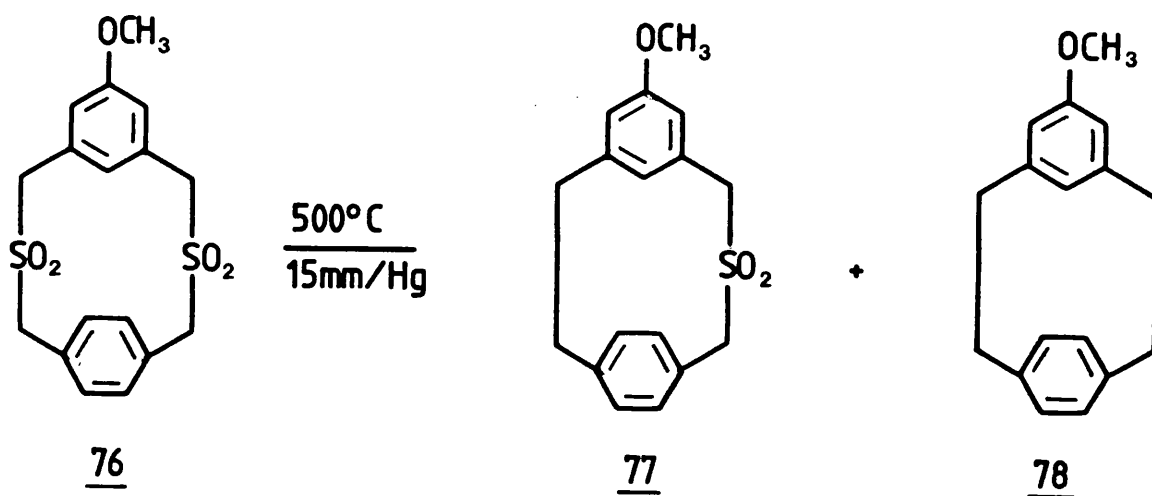
Thus the 'double' extrusions may occur in two distinct steps.

However ethene is eliminated in the thermolysis of (79)[39] (Scheme 14)

and this means that after the extrusion of the first sulphur dioxide

the second must be lost before the initially generated diradicals can

recombine; hence they must be lost virtually simultaneously.

79
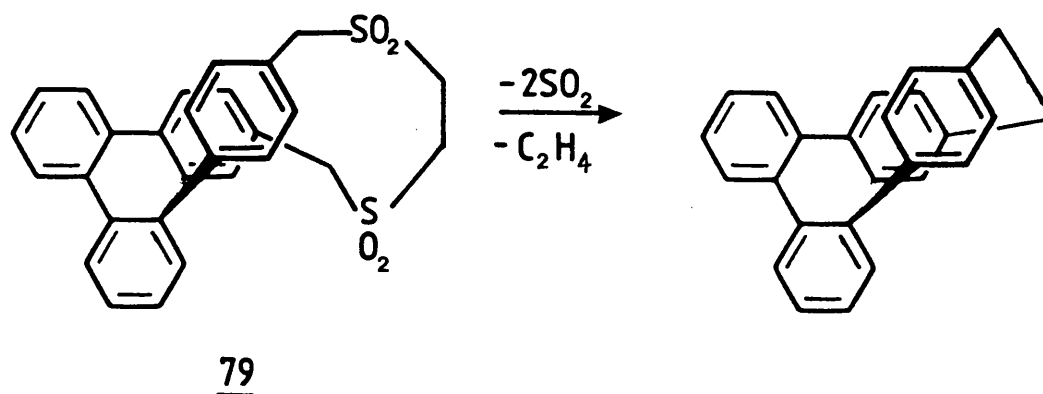
Scheme 14

Thermolysis of 9,10-dihydro-11-thia-9,10-ethanoanthracene

11,11-dioxides (80) when R_2=H at 300°C in a sealed tube at 0.5 mm/Hg

gave the substituted anthracenes (81)[40].

(a) R_1= H

(b) R_1= CH_3

80

81
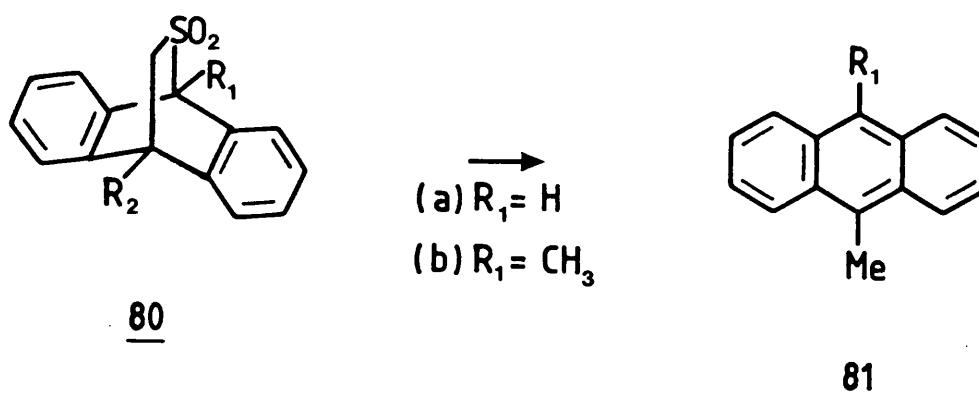
When R_2 is methyl this reaction is blocked, and the appropriately

substituted dibenzocycloheptene (82) is formed. Dibenzocycloheptenes

were also the products for all the compounds pyrolysed under flash

vacuum thermolysis conditions (600°C, 3x10-3 mm/Hg).

80 → **82**
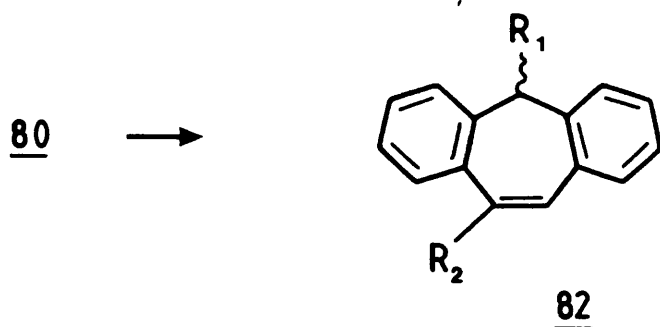
Static thermolysis of (83) at 300°C gave the dibenzocycloheptene (84)[41]. 1,4,5,8,9 -Pentamethylanthracene was not formed, presumably due to severe peri-interactions between the 1,8 and 9 methyl groups.

83 → **84**
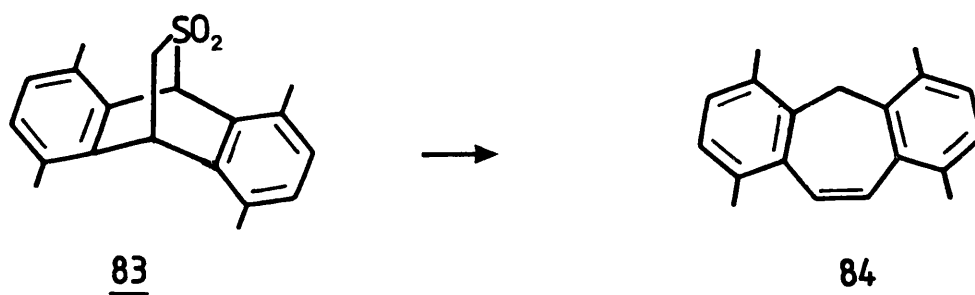
The static thermolysis of the disulphone (85) at 138°C for six hours gave a mixture of bibenzyl (86) and dibenzylsulphone (87)[42].

85 → **86**

41%

+

12%

87

-34-
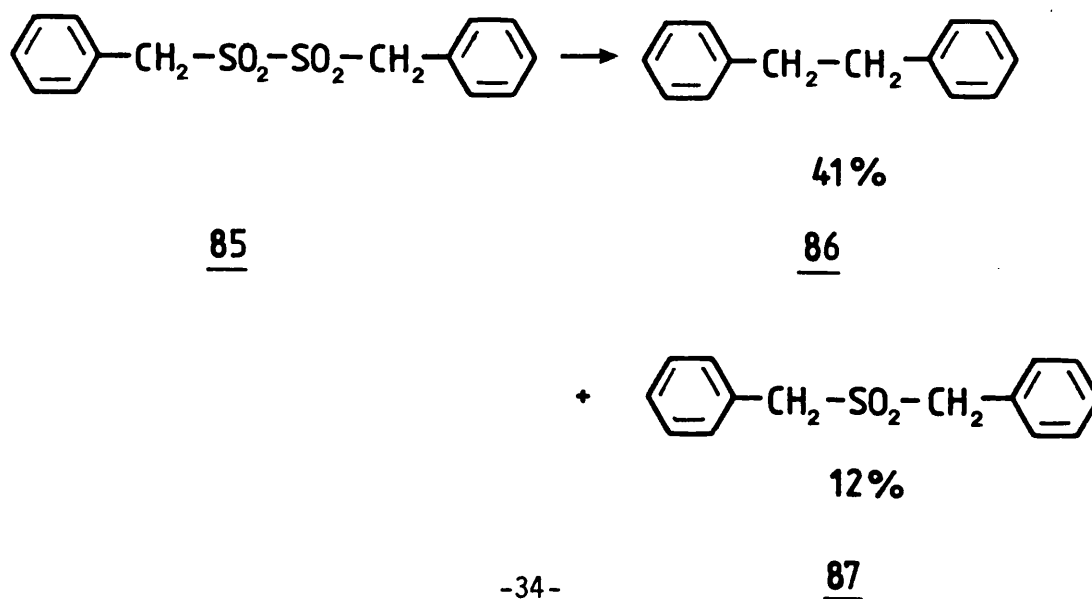
The isolation of (86) and (87) indicates the formation of benzyl
radicals in the thermolysis, but whether they are derived from the
disulphone directly or by loss of sulphur dioxide from $PhCH_2\overset{\bullet}{S}O_2$ is
unknown. Kinetic studies clearly indicated that the rate determining
bond fission was again homolytic.

Some cyclic sulphones behave in a similar manner to chain sulphones.
Pyrolysis of a cyclic sulphone with appropriate aryl substitution
generally gives ring contraction via loss of sulphur dioxide and
recombination of the benzyl radicals. Thermolysis of 2,4-diphenylthietan
1,1-dioxide (88) at 250°C for 0.5-1 hour gave a mixture of the cis-
and trans-diphenylcyclopropanes[43] (Scheme 15).

88   Scheme 15
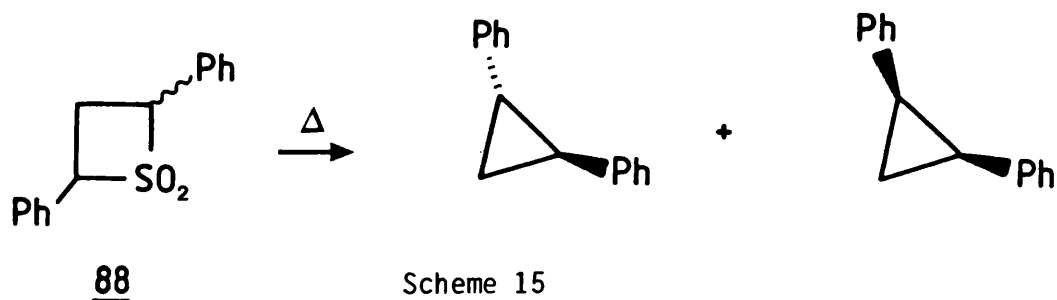
The cis-diphenylsulphone, the trans-diphenylsulphone and a mixture
of the two all gave a cis/trans ratio of the diphenylcyclopropanes of
approximately 0.135. Hence the benzyl radicals formed exist for a
sufficiently long enough time to exhibit no memory.

Thermolysis of trans-2,4-diphenylthietan 1,1-dioxide under flash
vacuum conditions at 400-500°C gave a cis/trans ratio of 0.30-0.34[44]
and thus the isomer product ratio appears to be thermodynamically
controlled.

Flash vacuum thermolysis of a sulphone incorporating benzylic stabilisation of the intermediate diradical also gives extrusion of sulphur dioxide. Finlay pyrolysed 2-phenylthietan 1,1-dioxide (89) and a number of 2,2-disubstituted derivatives under flash vacuum conditions[44]; at 450°C (89) gave, apart from unreacted starting material, exclusively phenylcyclopropane. At 600°C phenylcyclopropane represented 70% of the product mixture, the remainder consisting of β-methylstyrene and allylbenzene, while at 800°C these alkenes were the only compounds detectable in the product mixture. Thus at higher temperatures hydrogen migration competes successfully with recoupling of the radicals.

89
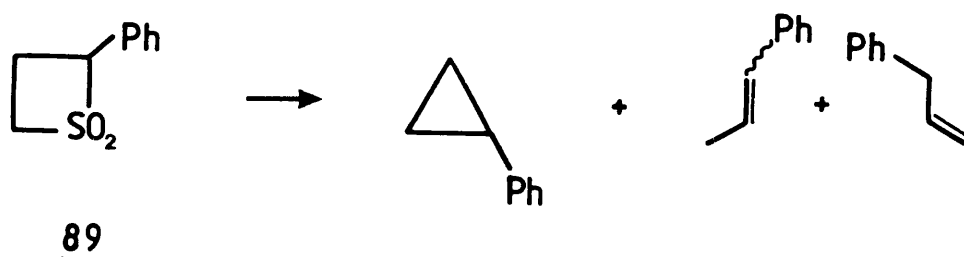
2-Alkyl-2-phenylthietan 1,1-dioxides gave slightly higher yields than (89) of the appropriate cyclopropanes at 600°C. The importance of the phenyl group being α to the sulphone group is illustrated by the fact that 3-phenylthietan 1,1-dioxide gave a 49% recovery of starting material for flash vacuum thermolysis at 800°C. The remaining material was made up of phenylcyclopropane and α-methylstyrene.

cis-2,3-Diphenylthiirane 1,1-dioxide (90) decomposes stereospecifically at 25°C to give cis-stilbene[45]. Likewise the trans isomer gives trans-stilbene. The rate of thermolytic decomposition of (90) was observed to increase markedly with increasing ionising power of the

solvent and this led to the consideration of an ionic intermediate. The authors however were in favour of a polarised transition state but with a diradical intermediate which would lose sulphur dioxide before bond rotation (Scheme 16).
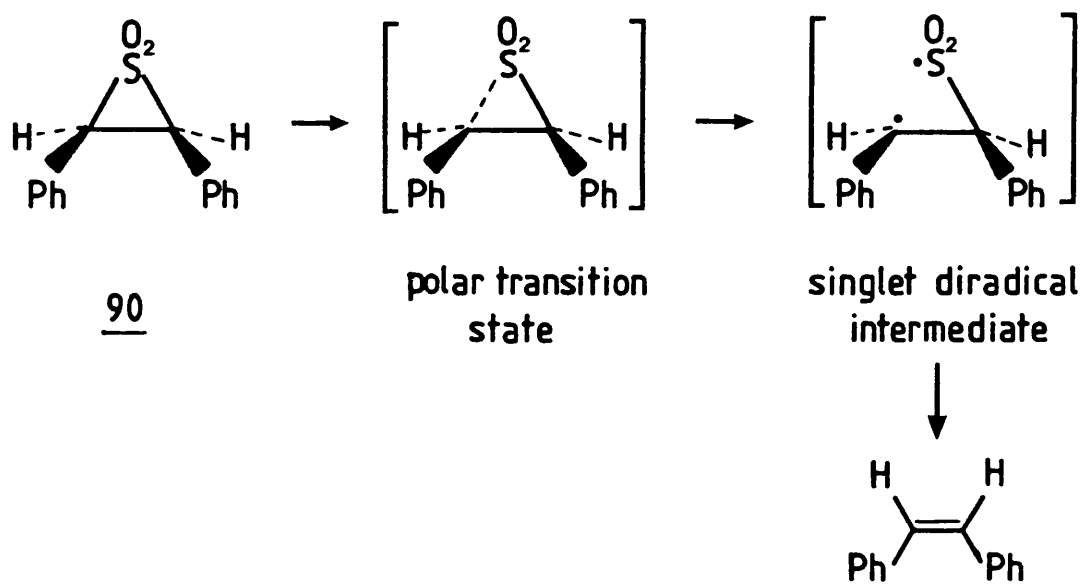
Scheme 16

However an ionic mechanism has been proposed in the thermolysis of 2-methyldiphenylsulphone (91) and related compounds[46] (Scheme 17). None of the biphenyl which would be expected from a radical mechanism was observed.
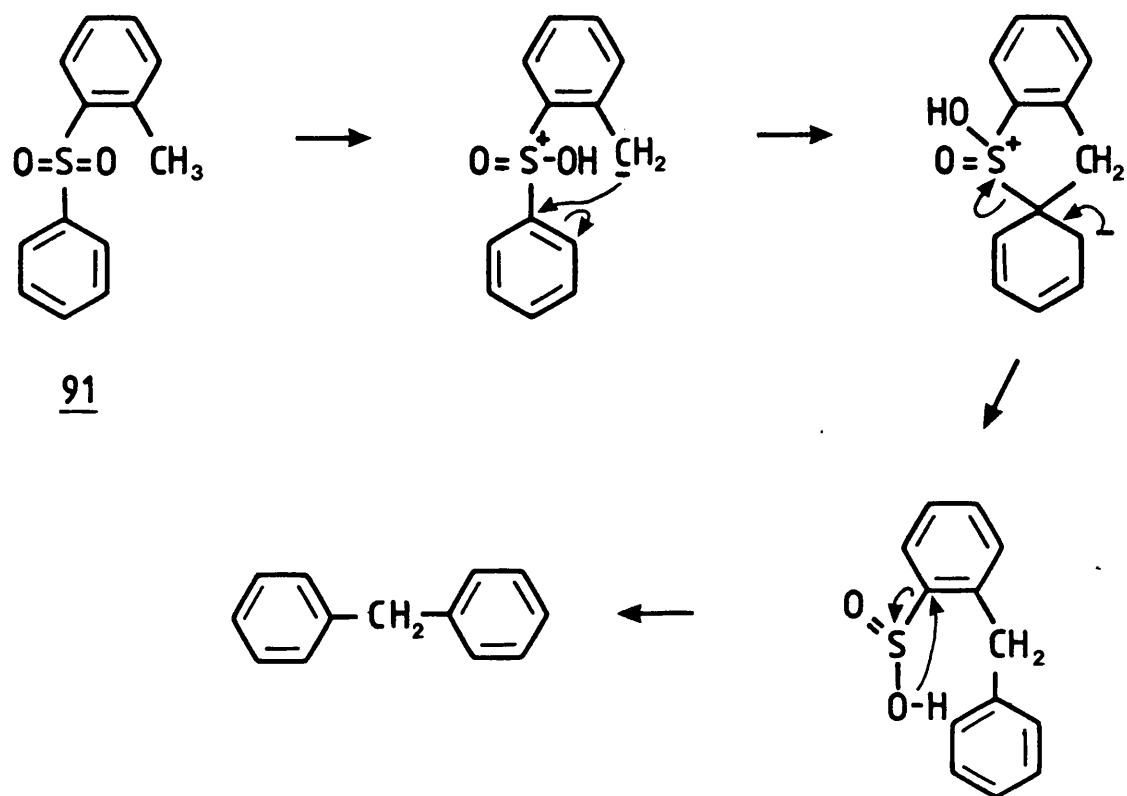
Scheme 17

A multi-centre transition state has been proposed for the elimination of sulphur dioxide from some acyclic allyl sulphones, for example from 3-benzylsulphonylbut-1-ene (92) which gives 5-phenylpent-2-ene on thermolysis[47] (Scheme 18).
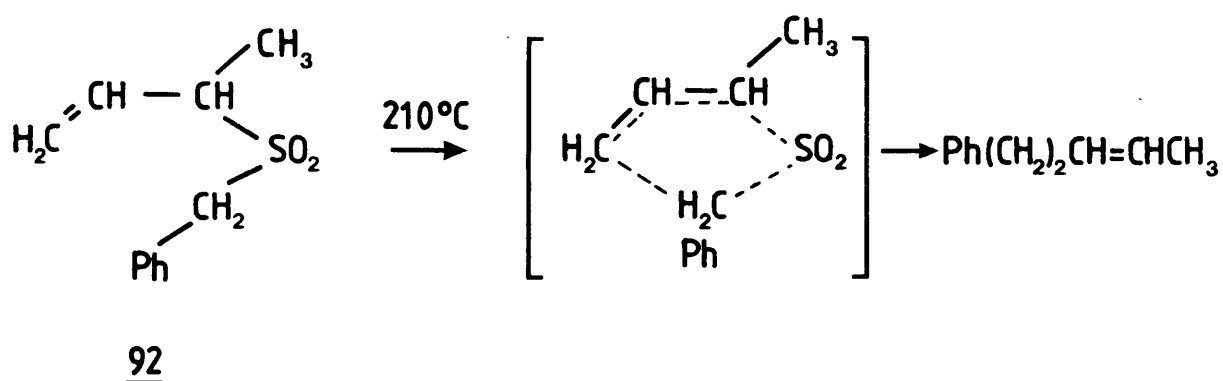
Scheme 18

Sulphones may also extrude sulphur dioxide on photolysis, but owing to the inability of saturated sulphones to strongly absorb ultraviolet light, a chromophore such as a phenyl group is needed. As with thermolyses, the presence of a radical stabilising group in the α-position causes the extrusions to occur more efficiently. Irradiation of (89) at 254 nm gave exclusively phenylcyclopropane[44]. Irradiation of 3-phenylthietan 1,1-dioxide under similar conditions gave recovery of starting material only. Photolysis of sulphone (93) gave extrusion of sulphur dioxide only when R was an aryl group[48] (Scheme 19). When R was alkyl no reaction occurred.
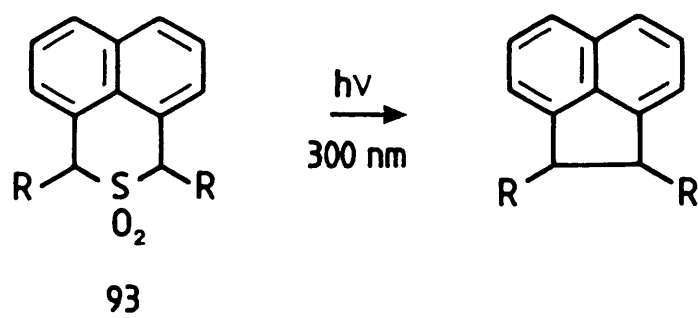
Scheme 19

Schultz and Schlessinger observed the loss of sulphur from the analogous sulphoxide when it was directly irradiated, yielding the appropriate pyran derivative. When the irradiation was sensitised, a ketone was the product[49] (Scheme 20).
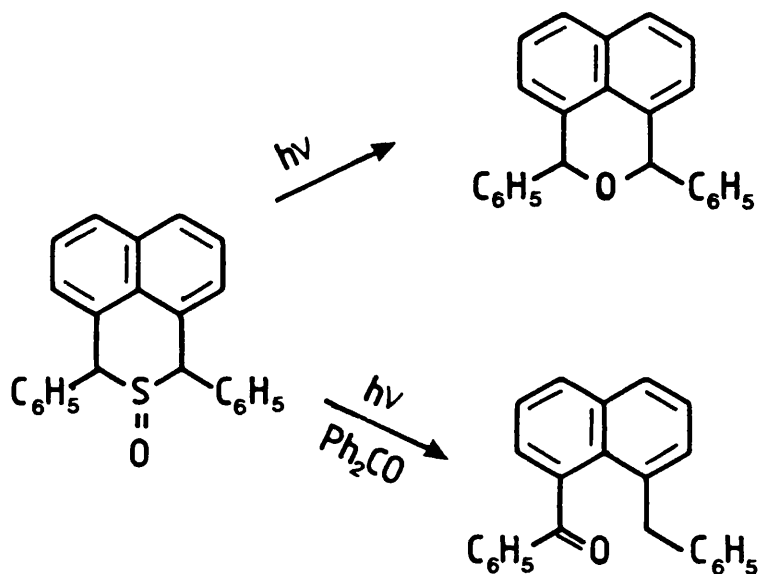
Scheme 20

Irradiation of diphenyl sulphone in benzene gives a mixture of biphenyl and benzenesulphinic acid, a radical mechanism via initial α-cleavage being proposed[50] (Scheme 21).
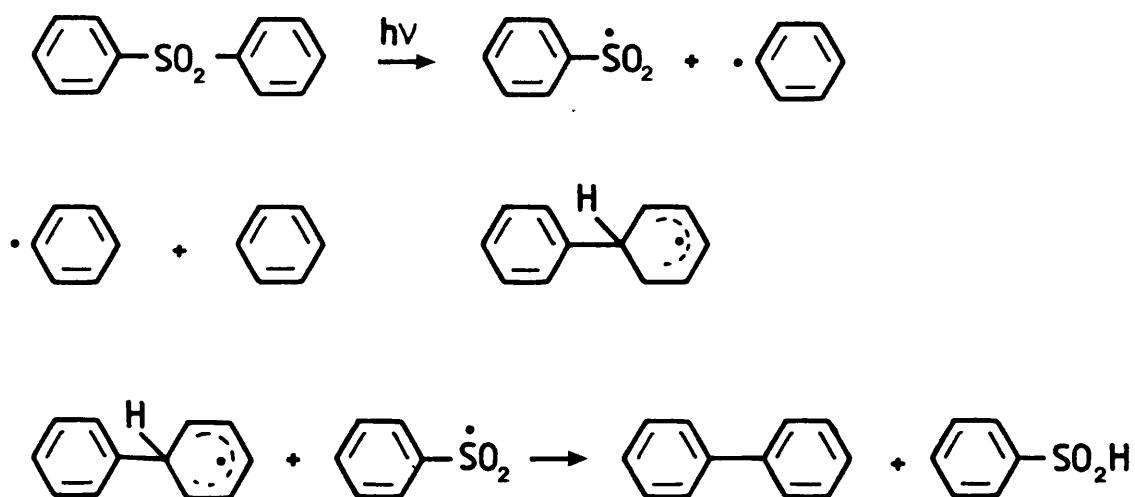
Scheme 21

The 1,8 bridged naphthalene sulphone (94) gives a dimer on photolysis with the diradical species (95) the probable intermediate[51].

2 [structure 94] ⟶ 2 [structure 95] ⟶ [dimer structure]

94   **95**
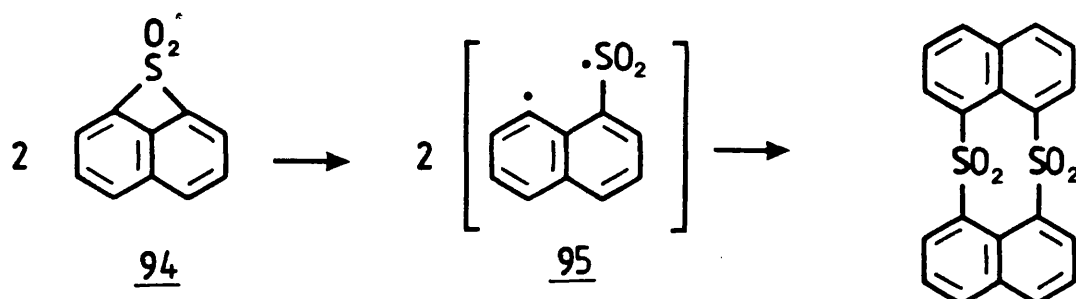
A phenyl group α to a sulphone group has been shown to stabilise not only the formation of radicals but also α-sulphonyl carbanions. Thus treatment of (89) with a powerful base, such as n-butyl-lithium, followed by addition of an alkyl halide gives the appropriate 2,2-disubstituted thietan sulphone in reasonable yield[44] (Scheme 22).

[structure 89] —nBuLi→ [structure, carbanion] —R-X→ [structure with R]

89
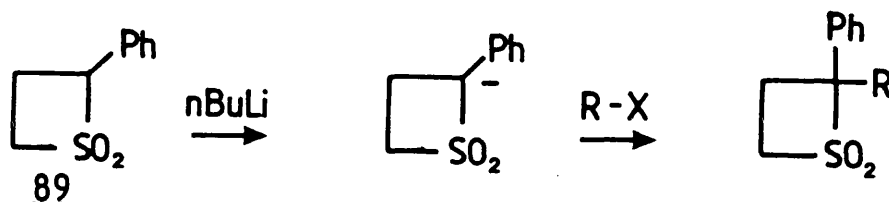
Scheme 22

The ability of thietan sulphones to both alkylate α to the sulphonyl group and ring contract to cyclopropanes led to their inclusion in Scheme 23. This is a Scheme that both exploits these abilities and which is considered to be a plausible retrosynthetic analysis of (96), an analogue of chrysanthemic acid esters.

[structure 96] ⇒ [structure] ⇒ [structure with OH]

96

Scheme 23

89 ⇐ [structure]

-41-
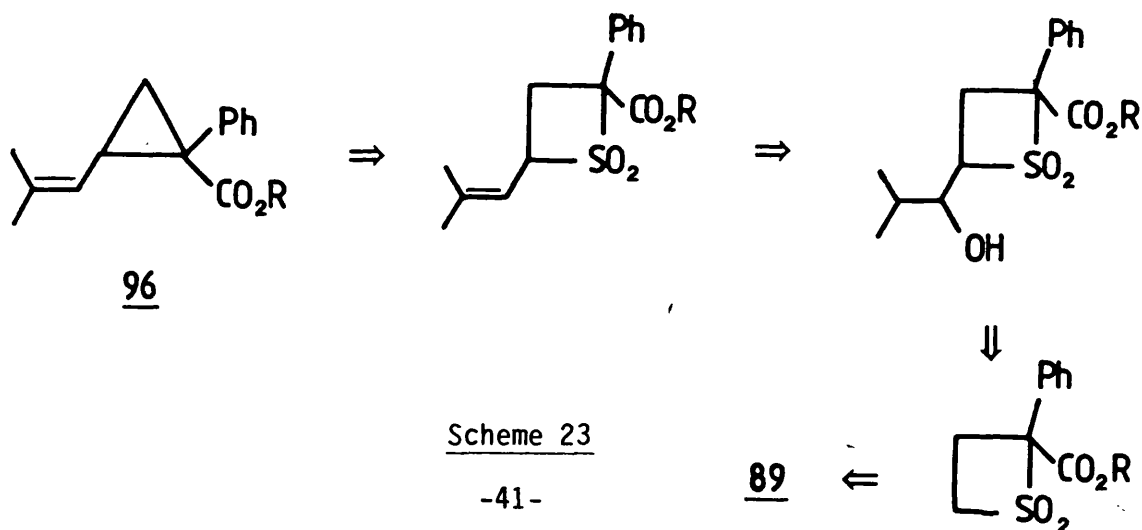
The incorporation of the olefinic sidechain was envisaged as possibly

being accomplished by the reaction of an α-sulphonyl carbanion with

isobutyraldehyde, followed by dehydration and, with a view to these

two steps, the condensation of (89) with aldehydes in general was to

come under study.

Compound (89) has previously been prepared by the method described

by Schaal[52] and summarised in Scheme 24.
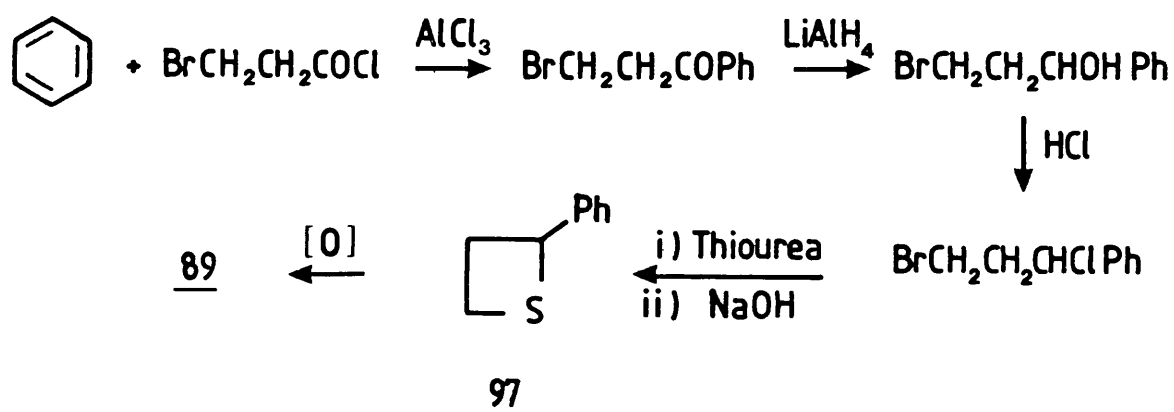
Scheme 24

The synthetic utility of this route for a bulk or commercial

preparation of (89) would tend to be limited by the expense of 3-

bromopropanoyl chloride and in view of the potential synthetic

importance of the sulphone, a new route was desired.

1,3-Dichloro-1-phenylpropane (99) was studied as a possible

intermediate for such a route. This compound has previously been

prepared by Shorygina[53] from 4-phenyl-m-dioxane (98), which in turn

has been prepared by Shortridge[54]. Both these preparations were

reported as being in excellent yield and using readily available materials.

$$\text{Ph} + 2CH_2O \xrightarrow[\text{84-88\%}]{\text{H}^+} \underset{\underline{98}}{\text{Ph}} \xrightarrow[\text{95\%}]{\text{PCl}_5} \underset{\underline{99}}{\text{Ph}}$$
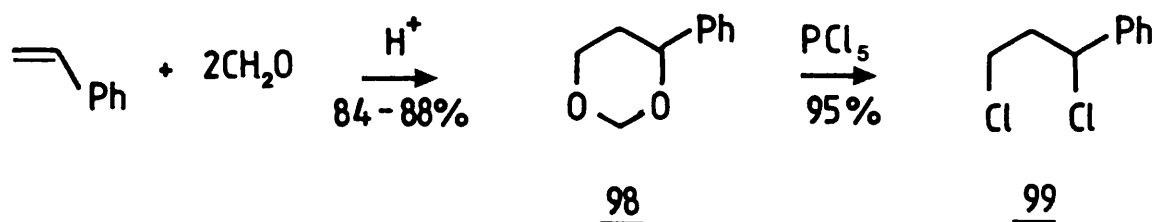
However, the cyclisation of dichlorides into thietans does not appear to have previously been studied. Fidler et al reported that the conversion of dibromides into thiacyclopentanes and thiacyclohexanes can be accomplished in very good yields using sodium sulphide[55]. However when 1-bromo-5-chlorohexane was used in such a preparation, the yield was only moderate (Scheme 25).

$$\text{Br} \overset{}{\underset{}{\diagup}} \text{Cl} \xrightarrow[\text{54\%}]{\text{Na}_2\text{S}} \text{S} \overset{}{\underset{}{\diagup}} \text{Me}$$
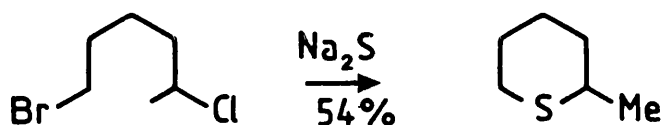
Scheme 25

Synthesis of the more strained thietan ring under similar conditions has been accomplished by Finlay: use of sodium sulphide in the cyclisation step of Scheme 24 led to an increased yield of 2-phenyl thietan (97) from 30% to 73%[44].

2.2 Preparation of 1,3-Dichloro-1-phenylpropane (99)

4-Phenyl-m-dioxane (98) was prepared by heating a mixture of styrene and excess aqueous formaldehyde solution under reflux in the presence of a catalytic amount of sulphuric acid, in a yield consistent with

-43-

those observed by Shortridge[54]. This dioxane was then used in the

preparation of 1,3-dichloro-1-phenylpropane (99) by methods described

by Shorygina[53]. However the yields quoted by this author were not

found to be reproducible. Maintaining a stirred solution of (98) in

thionyl chloride at 70-80°C for four hours gave, on work up, a viscous

dark tar, from which only a negligible amount of the desired compound

could be isolated. Following the reaction by g.l.c showed that after

90 minutes the quantity of the dioxane (98) exceeded that of the

dichloride (99), rendering a 50% yield (quoted by the author for this

reaction time) impossible.

The reaction of (98) with phosphorus pentachloride was found to be

extremely lethargic. A reaction mixture of the two compounds in

carbon tetrachloride was stirred at room temperature for a total of

approximately six weeks and at 40-60°C for a total of approximately

six days. At the end of this period, the reaction was shown by g.l.c

to be incomplete.

The method eventually adopted for the preparation of (99) was to

allow partial chlorination of the dioxane (98) by treatment with

phosphorus pentachloride and, after work up, to complete the step by

heating and stirring the product in thionyl chloride at 70-80°C. A

yield of 61% was achieved by this procedure.

Alternatively the reaction of (98) with phosphorus pentachloride,

followed by fractional distillation of the partially chlorinated

product mixture was observed to give a 47% yield of (99).

2.3 Preparation of 2-Phenylthietan (97)

The cyclic sulphide (97) was prepared by heating the dichloride (99) under reflux in an aqueous alcoholic solution of sodium sulphide. Over a series of experiments yields were in the range 45-53%. This is lower than that quoted by Finlay[44] with respect to the preparation of (97) from 3-bromo-1-chloro-1-phenylpropane but this is not surprising in view of the fact that the difficult step of the nucleophilic displacement of the primary halide by a sulphide ion was accomplished using a chloride rather than a bromide. Certainly the yields compare favourably with that observed for Scheme 25. 2-Phenylthietan 1,1-dioxide (89) was obtained by oxidation of (97) with m-chloroperbenzoic acid.

A summary of the new procedure for the preparation of this sulphone is given in Scheme 26.
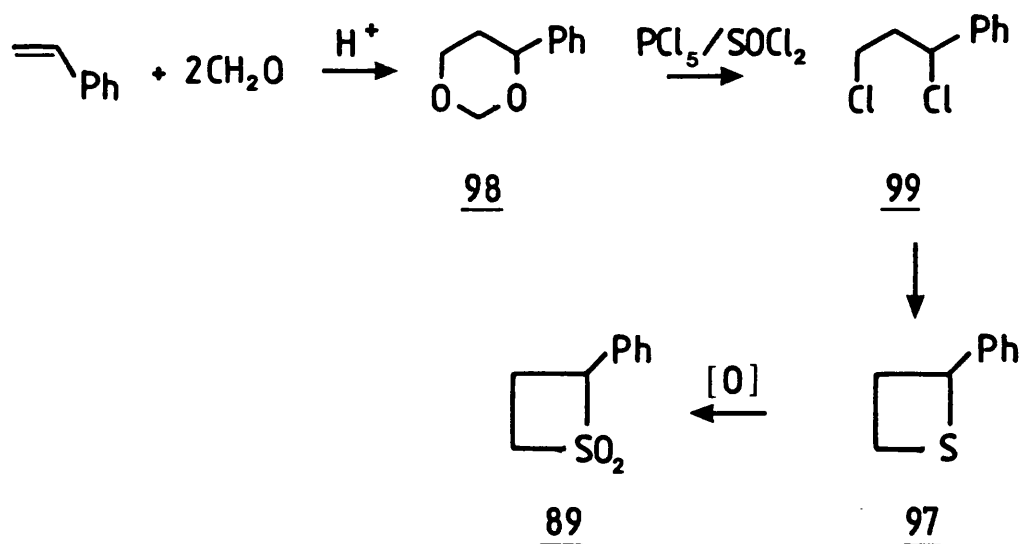
Scheme 26

2.4   Preparation of 2-(1-Hydroxyalkyl)2-phenylthietan 1,1-dioxides

Treatment of a dry ethereal suspension of 2-phenylthietan 1,1-dioxide (89) with a slight excess of n-butyl-lithium at -78°C, followed by the addition of an aliphatic aldehyde afforded the respective alcohol in a yield of 30-35%, as shown in Table 2.1.

a) $R = CH_3$

b) $R = CH(CH_3)_2$
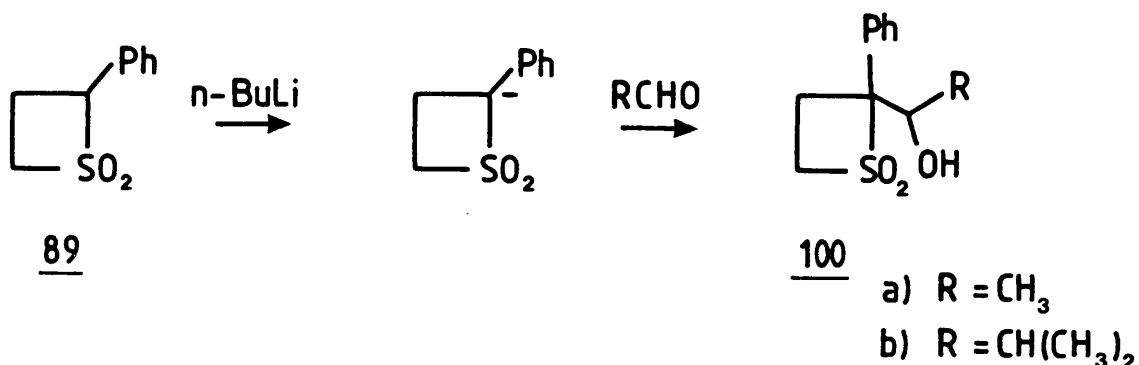
Table 2.1:-   Preparation of 2-(1-Hydroxyalkyl)2-phenylthietan
               1,1-dioxides (100), Using n-BuLi

Aldehyde	Product	Yield %
CH_3CHO	100a	30
$(CH_3)_2CHCHO$	100b	35

Repeating the preparation of (100a) using dry THF, but otherwise keeping reaction times and conditions the same, led to a slightly reduced yield of 23%.

The use of THF in metalation reactions became increasingly popular in the 1960's when Gilman et al showed that generally compounds were metalated more rapidly and gave higher yields of the desired product when this solvent was used instead of diethyl ether[56-58]. However carbanions often have a lower stability in THF than in diethyl

ether and this has led to the development of the mixed solvent system
THF-diethyl ether which can further improve yields. For the dimetalation
of diphenyl ether, for example, a THF:ether ratio of 1:1.3 was
recommended[58]. In view of the findings of Gilman's group, it would
appear that the lower yield of (100a) using THF can be accounted for
by the lower stability of the sulphonyl anion in this solvent than in
diethyl ether. However, owing to insufficient time, no effort was
made to maximise the yield of the reaction in either solvent.

2.5 Attempted Preparation of 2-(2-Methylprop-1-enyl)2-phenylthietan 1,1-dioxide (101)

Attempts were made to prepare 2-(2-methylprop-1-enyl)-2-phenylthietan
1,1-dioxide (101) from the corresponding alcohol (100b).
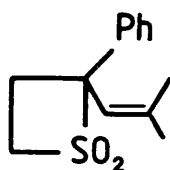
101

In order to avoid a carbonium ion α to the 4-membered ring, which
may have facilitated ring expansion, dehydration procedures not
thought to involve carbonium ions were used.

The initial attempt used the reagent HMPT. Monson and Priest[59,60]
reported the dehydration of primary and secondary alcohols with this
reagent at 220-240°C, and took the absence of rearrangement products
(in reactions where rearrangements are known to occur when a carbonium
ion intermediate is involved) as proving an E2 mechanism. This,
however, was disputed by Dubois et al[61]. A fuller discussion of the
mechanism here is unwarranted since heating (100b) in HMPT for two

hours at 220-240°C led to a number of decomposition products, none of which could be identified.

Appel and Wihler reported the dehydration of alcohols using triphenylphosphine and carbon tetrachloride in acetonitrile[62]. However heating a mixture of the alcohol (100b), carbon tetrachloride and triphenylphosphine in acetonitrile under reflux overnight led to a nearly quantitative recovery of the starting alcohol. The desired olefin was not isolated from, or identified in, either the crude product mixture or in the small quantity of products not corresponding to (100b).

2.6 Preparation of 2-Alkoxycarbonyl-2-phenylthietan 1,1-dioxides

Finlay[44] reported that the anion generated from the sulphone (89) did not react with ethyl chloroformate and that only starting materials were recoverable. However, this was not found to be strictly true. In one experiment, treatment of (89) with n-butyl-lithium followed by addition of ethyl chloroformate gave, after chromatography on alumina, a low yield of 2-ethoxycarbonyl-2-phenylthietan 1,1-dioxide (102). Some of the starting sulphone (89) was also isolated but curiously it was recovered from the chromatography column after (102).

89   102
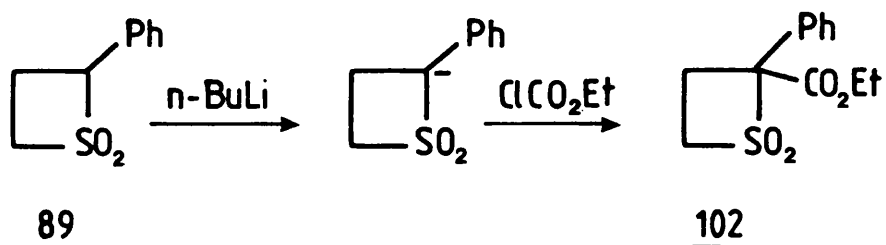
A series of further attempts at the preparation of (102) was made

using a similar procedure to that which had proved successful.

However none of the desired sulphone ester was ever isolated. The

starting sulphone was always recovered, despite the fact that by

n.m.r. spectroscopy it always appeared to be absent in the crude

product mixture. The method of attempted purification was always

column chromatography, since attempts at crystallisation always

failed. Indeed when (102) was obtained in the pure form, it proved

very difficult to recrystallise.

Attempts at the preparation 2-methoxycarbonyl-2-phenylthietan 1,1-

dioxide (104) proved more successful. The anion generated by treatment

of (89) with n-butyl-lithium was quenched with carbon dioxide and

acidic work-up afforded the carboxylic acid (103) in 89% yield.

Esterification with diazomethane could be accomplished in 59-66%

yield.

$$\underline{89} \quad \begin{array}{l} \text{1) } n\text{-BuLi} \\ \hline \text{2) } CO_2 \\ \text{3) } H^+ \end{array} \longrightarrow \quad \overset{Ph}{\underset{SO_2}{\bigsqcup}} CO_2H \quad \overset{CH_2N_2}{\longrightarrow} \quad \overset{Ph}{\underset{SO_2}{\bigsqcup}} CO_2Me$$

$$\underline{103} \qquad\qquad \underline{104}$$
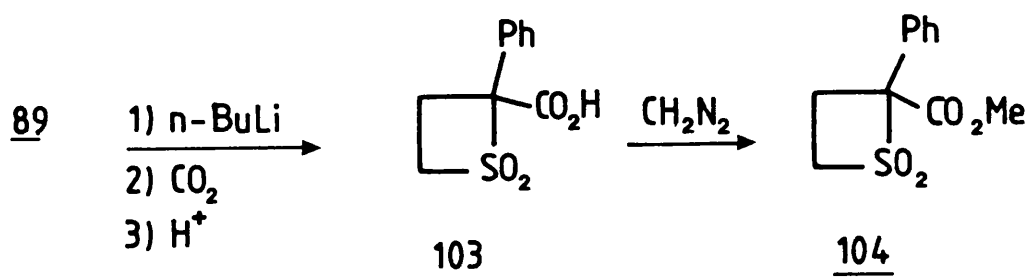
A sample of (104) was eluted through alumina while another was

eluted through silica. In both cases the time spent on the column

was in the order of 20 minutes and in both cases the material recovered

was a mixture of (89) and (104). This suggests that the major

difficulty associated with the preparation of (102) is the instability

of such sulphone esters on chromatography packing. Similar sulphone

esters were eluted through chromatography columns during the course of

the work for Chapter 3, and a discussion of this phenomenon will

appear in that chapter.

2.7 Photolysis of 2-Alkoxycarbonyl-2-phenylthietan 1,1-dioxides

Photolysis of the methyl ester (104) at 254 nm for 10 hours gave,

after chromatography on silica, an 82% yield of the cyclopropane

(105) which was identified by comparison with 'H n.m.r. data previously

published[63].

Photolysis of (102) at 254 nm for 2-3 hours gave only one compound

by t.l.c., the n.m.r. spectrum of which corresponded to that anticipated

for ethyl 1-phenylcyclopropane carboxylate (106). The mass spectrum

also corresponded to that expected. This compound has previously

been prepared by the groups of Kondo[64] and Lauger[65].
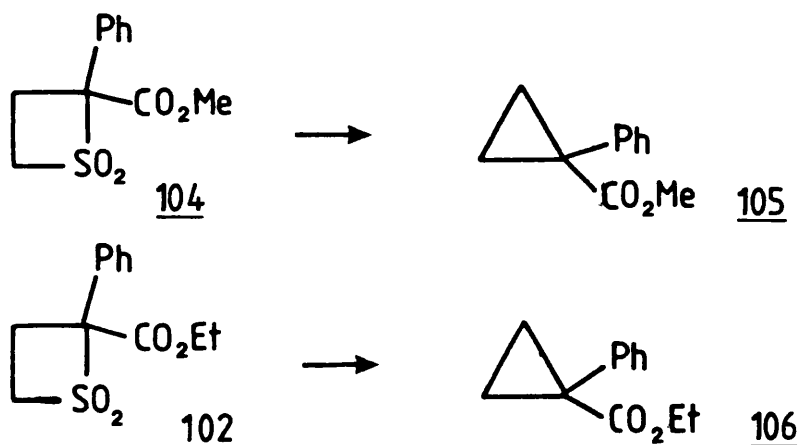
These results are consistent with the observations of Finlay[44] in

the photolysis of 2-alkyl-2-phenylthietan 1,1-dioxides, which gave

the appropriate cyclopropanes as the only products by g.l.c. No

comment can be passed on the ability of an alkoxycarbonyl group to

act as a chromophore or as a radical stabiliser in these photolyses,

as the facile extrusions of sulphur dioxide that were observed can be

accounted for by the presence of the 2-phenyl group.

2.8 Attempted Preparation of 2-Methoxycarbonyl-4-(2-methylpropan-1-ol)-2-phenylthietan 1,1-dioxide (107)

The title compound was of interest because it was a possible intermediate in Scheme 23, but attempts to prepare it from (104) proved unsuccessful.
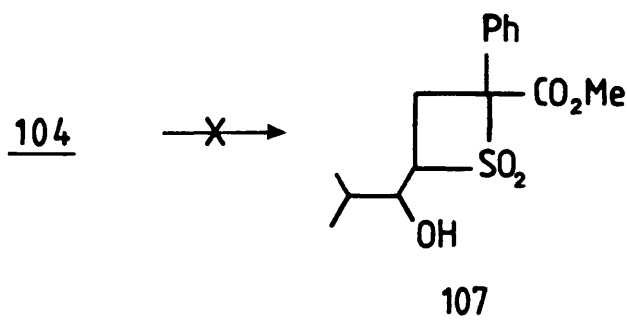
Treatment of a suspension of (104) in dry ether with an equivalent amount of LDA at -78°C failed to produce a solution, instead a precipitate remained even when warmed to room temperature (this contrasts with the behaviour of a suspension of (89) in dry ether which gives a solution when treated with a strong base). Addition of isobutyraldehyde at -78°C and a gradual warming to room temperature caused the suspension to give way to a solution. On work up, the crude product mixture appeared to consist of a considerable number of compounds by t.l.c. Flash chromatography failed to yield any identifiable compounds.

When the experiment was repeated, but with THF replacing ether as solvent, treatment of a solution of (89) at -78°C with an equivalent amount of LDA gave a green solution. Stirring at -78°C for a further half an hour was followed by addition of isobutyraldehyde. Work up again revealed a large number of compounds present in the crude product and, after flash chromatography, a trace amount of the starting

sulphone was the only identifiable compound. The bulk of the product mixture appeared to consist of aliphatic hydroxy compounds. None of the desired product was isolated or detected.

In an effort to establish if this behaviour was general for thietan sulphones where there is no phenyl group present to stabilise any carbanion formed, a similar condensation was attempted using thietan 1,1-dioxide (108). A suspension of (108) in dry ether at -78°C, with a small amount of hexamethylphosphoric triamide added, was treated with an equivalent amount of n-butyl-lithium, resulting in a reaction mixture that was gelatinous in appearance. Warming to room temperature produced no apparent change. However, after recooling to -78°C, the addition of isobutyraldehyde caused the immediate disappearance of the gel. Work up and chromatography did not yield any identifiable products, although a number of aliphatic alcohols appeared to be present.

When a suspension of (108) in ether was treated with a 1.1 equivalent amount of LDA a gelatinous suspension again appeared. Dry carbon dioxide was bubbled through the reaction mixture but only a tiny amount of 2-carboxythietan 1,1-dioxide (109) was isolated.
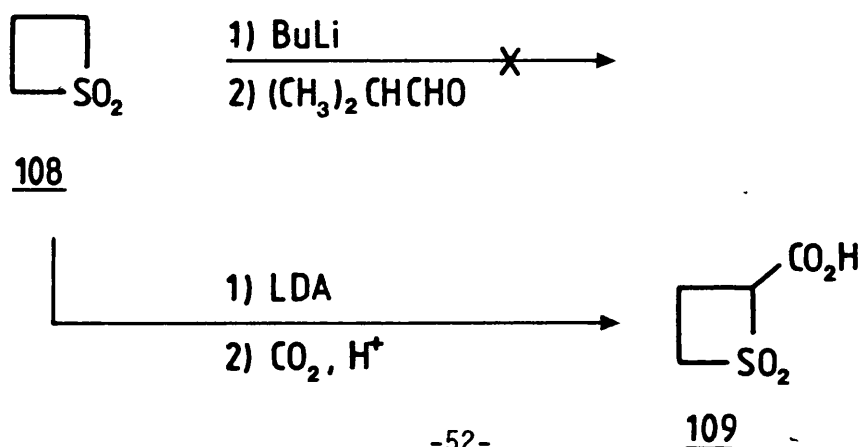
It would seem, therefore, that the inability of the thietan sulphones (104) and (108) to give successful condensations with isobutyraldehyde is not the result of non-reactivity of the sulphones with strong base, but the dominance of one or more undesired reactions which give rise to decomposition products.

Kotin has reported similar difficulties in the reaction of a Grignard reagent prepared from (108) with a series of carbonyl compounds[66]. The desired hydroxy compounds were obtained in two cases, namely the cyclohexanone and benzaldehyde derivatives, but in generally poor yields. No desired products whatsoever were obtained when the Grignard reagent was treated with a substituted benzaldehyde, acetone or formaldehyde.

A possible explanation for the lack of success experienced in the condensations involving (108) and (104) is given in Scheme 27. In the absence of a phenyl group to stabilise any α-sulphonyl carbanion formed it would seen plausible that the base could remove a β-hydrogen thereby allowing ring opening. The product of such a step could then undergo further fragmentation or rearrangement.
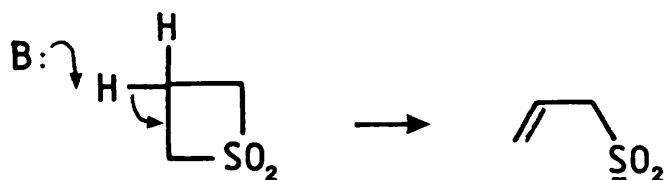
Scheme 27

Subjecting a thietan sulphone containing no β-hydrogens to similar reaction conditions would be helpful in attempting to corroborate this suggestion. If Scheme 27 is correct then such a sulphone should be protected from this type of attack, allowing the desired alkylation products to be obtained. 3,3-Dimethylthietan 1,1-dioxide, a thietan sulphone containing no β-hydrogens, was studied during the work for Chapter 3, and its reaction with strong base and a series of aldehydes is reported therein.

2.9   Mass Spectral Studies

This chapter has included the photolysis of two compounds, (102) and (104), and their mass spectra at low ev are given in Figures 2.1 and 2.2 respectively. On photolysis (104) extrudes sulphur dioxide and this is also the dominant mass spectral process at 30 ev, giving the ion m/e 176. Competing with this is loss of the methoxycarbonyl group, giving the ion m/e 181. Not only does this latter ion have a significant level of occurrance (50% of the base peak) but the ion m/e 176 itself loses its methoxycarbonyl group to give the ion m/e 117. A metastable peak at m/e 78 substantiates this. Strangely, there is no evidence that the last step of the reverse series of extrusions 250 $\rightarrow$ 181 $\rightarrow$ 117 occurs, owing to the absence of a metastable peak at m/e 176. A summary is given below (Scheme 28).

At 70 ev generation of the ion m/e 117 is by far the most commonly occurring process, with the next major ion at m/e 105 having a relative 22% occurrance. It is not clear how this latter ion, believed to be $C_8H_9^+$, is derived.
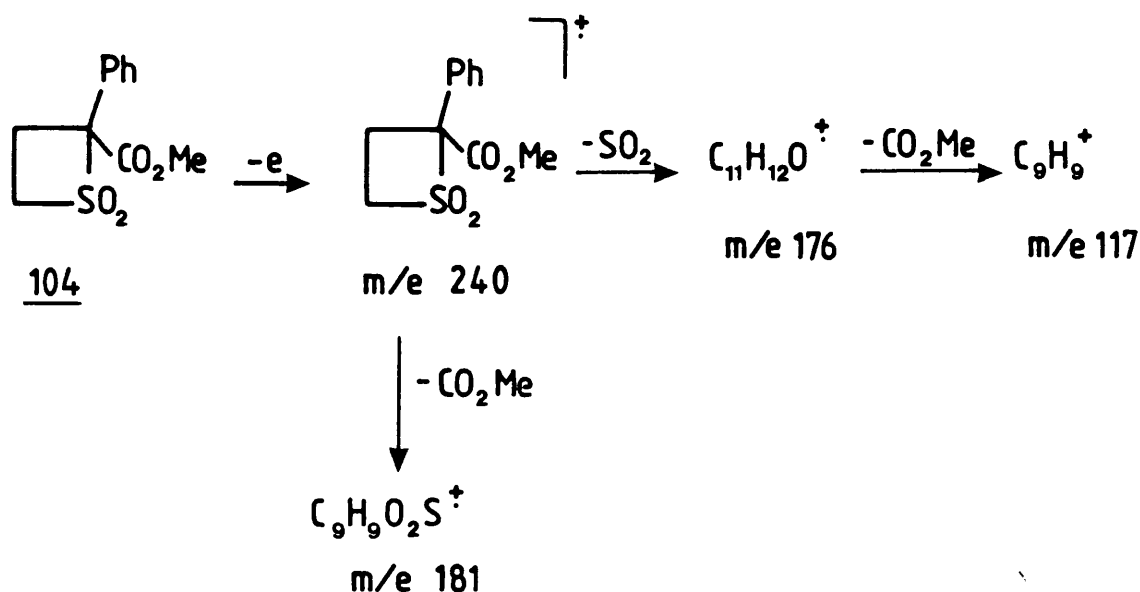
Scheme 28

The mass spectrum of (102) (Figure 2.2) shows great similarity to that of the methyl ester. At 25 ev the dominant process is again loss of SO_2, corresponding, as previously, to the photochemical behaviour of the sulphone in question. However, two processes are observed that were absent in the mass spectrum of (104). The first of these is the loss of $[CO_2CH_2CH_2]$ to give ion m/e 182, a fragmentation possibly best explained by Scheme 29.
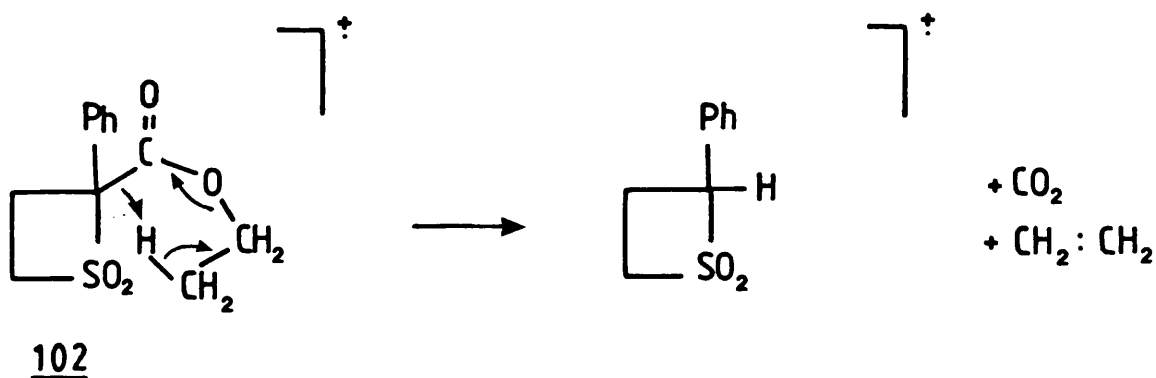
Scheme 29

The second is the loss of [$SO_2CH_2CH_2$], a process which occurs in two stages, namely initial extrusion of sulphur dioxide to give base ion m/e 190, then loss of ethene. A metastable peak at m/e 138 provides good evidence for this order of events. At 70 ev ion m/e 117 is again the base peak.

Ion m/e 117 also forms the base peak in the spectrum of (100a) (Figure 2.3). However, in this case loss of the sidechain from the benzylic position predominates over loss of sulphur dioxide, the latter giving a small but distinguishable peak at m/e 162. For (100b) (Figure 2.4) unaccompanied extrusion of SO_2 is almost non-existant, the ion m/e 190 giving only a minute peak. The base peak is ion m/e 147, corresponding to loss of sulphur dioxide and the sidechain isopropyl group. A metastable peak at m/e 114 indicates that the loss of the isopropyl group occurs first with subsequent loss of SO_2. Indeed unaccompanied loss of the isopropyl group occurs to only a very small extent, with the peak it gives at m/e 211 even smaller than that at m/e 190.

FIGURE 2.1
Mass spectrum of (104) at 30 eV.

FIGURE 2.2
Mass spectrum of (102) at 25 eV.

FIGURE 2.3
Mass spectrum of 100(a)
at 70 eV.

FIGURE 2.4
Mass spectrum of 100(b)
at 70 eV.
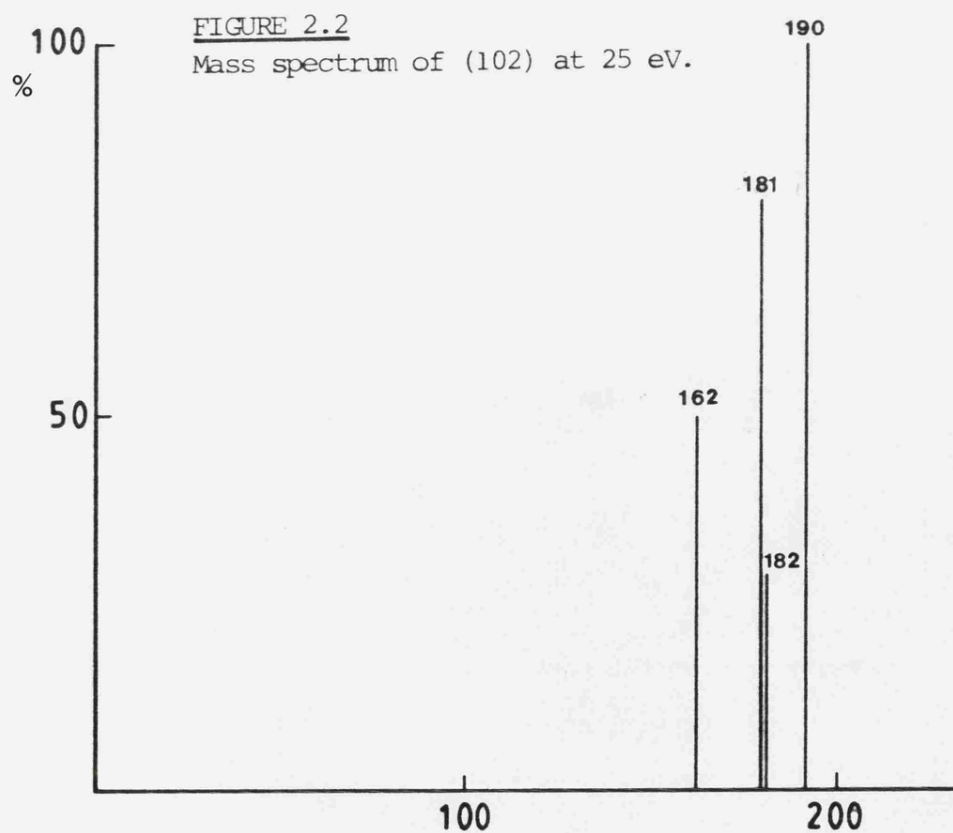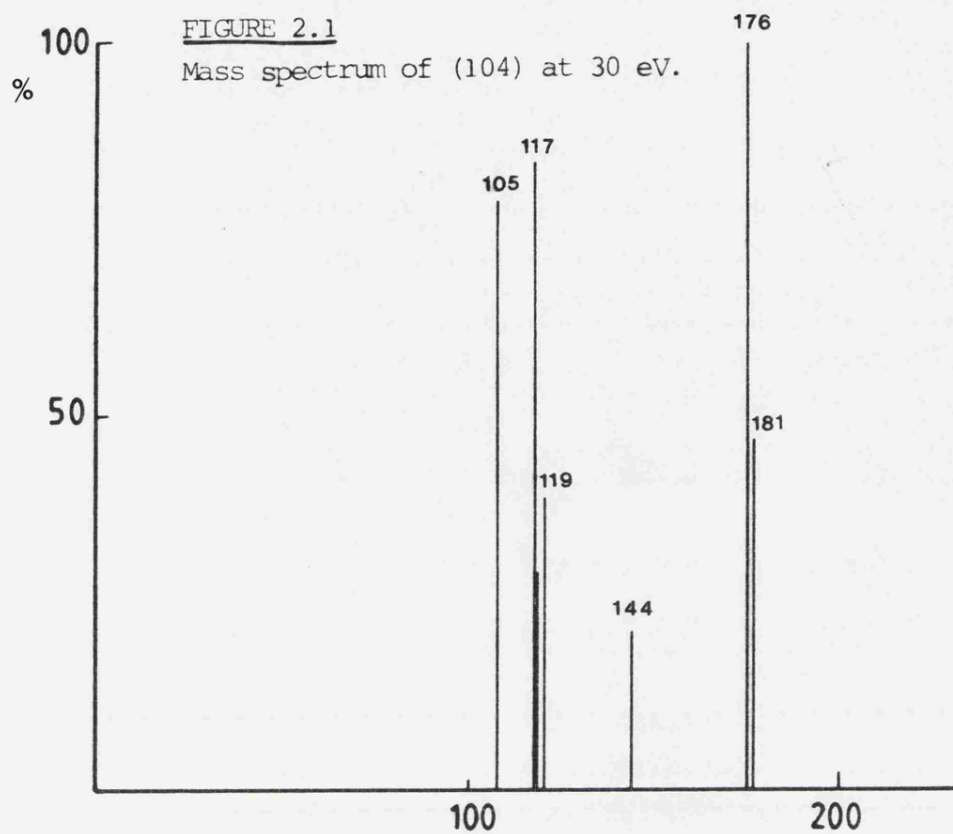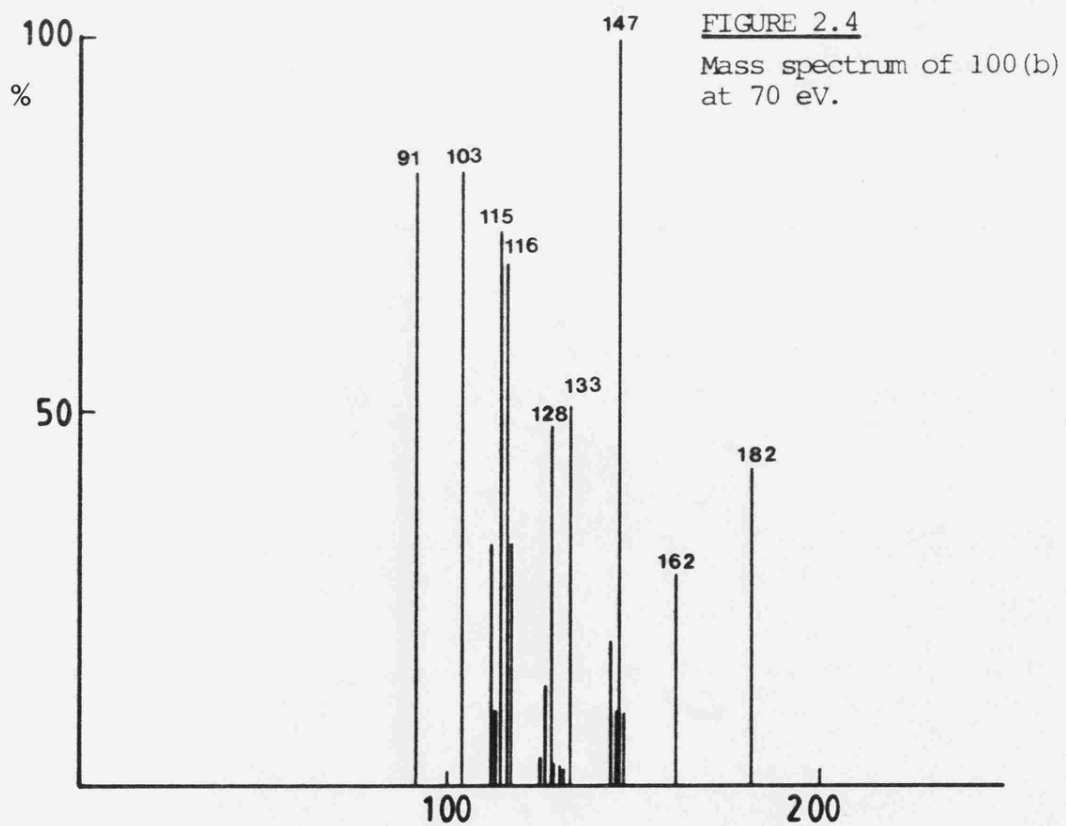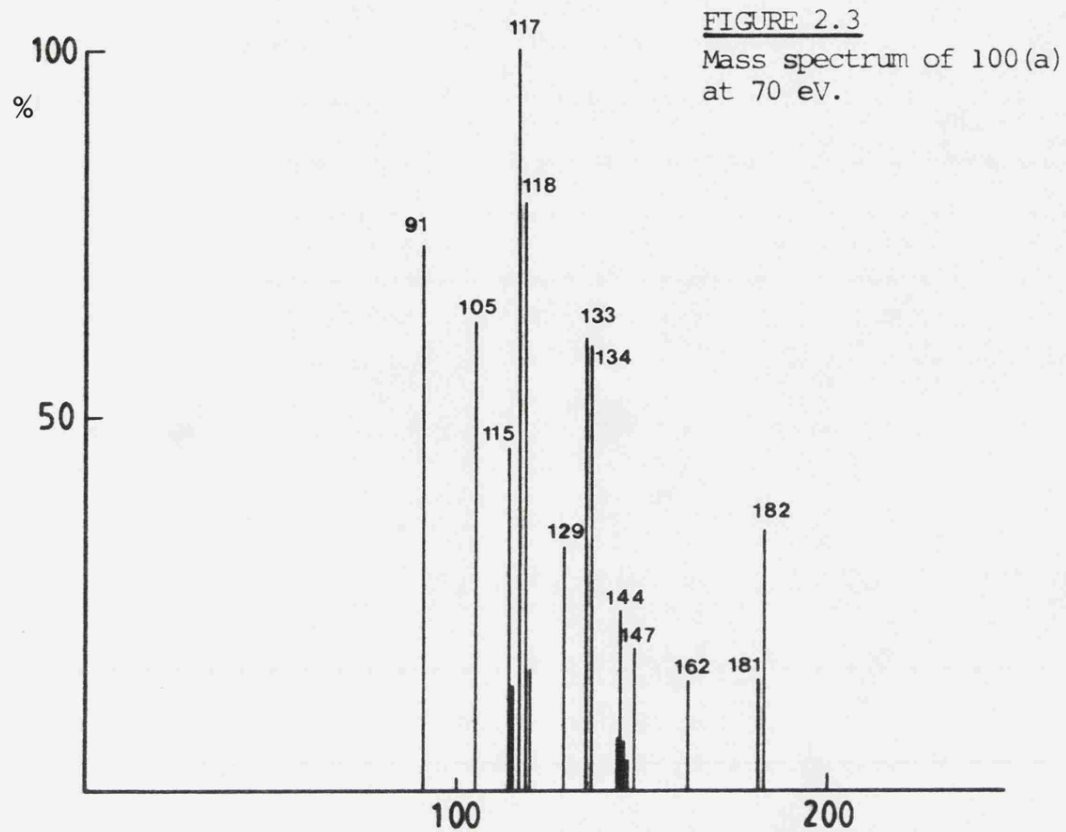
CHAPTER THREE

PREPARATION AND PYROLYSIS OF SOME 3,3-DIMETHYLTHIETAN 1,1-DIOXIDES

3.1 Introduction

The absence of a β-γ double bond in a 5-membered ring sulphone makes the extrusion of sulphur dioxide more difficult than for the dihydrothiophene sulphones discussed in Chapter One. The extrusion of sulphur dioxide from (110) proceeds only at a much higher temperature and in a lower yield[67] than in the case of (111) where the reaction presumably proceeds via the enol form[68]. The authors proposed a diradical intermediate for the thermolysis of (110) rather than a concerted 1,5 chelotropic elimination[66].

$$\underline{110} \qquad \sim 60\%$$

$$\underline{111} \qquad 100\%$$
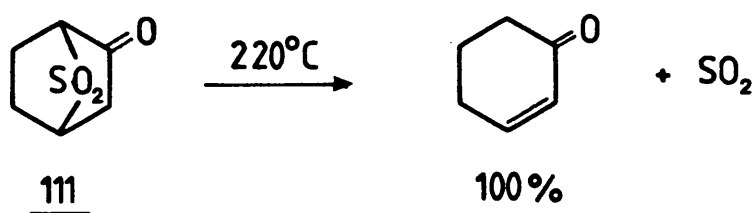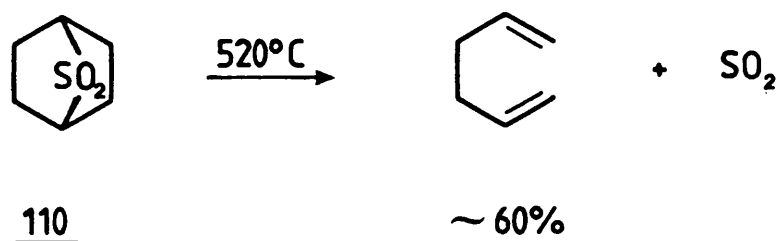
Dimethylsulpholanes clearly show a lack of concertedness in giving a mixture of cis- and trans-but-2-enes[69] (Scheme 30).

$$\xrightarrow[\substack{-C_2H_4 \\ -SO_2}]{>500^\circ}$$
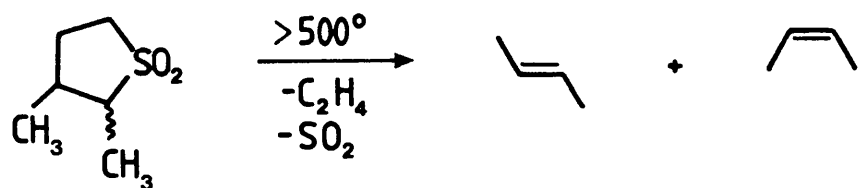
| 1) | 95% cis | 36 ± 6% | 53 ± 3% |
| 2) | 90% trans | 51 ± 6% | 40 ± 3% |

Scheme 30

It seems feasible, therefore, to suggest diradicals, (112) and (113), or zwitterions as intermediates in a mechanism where internal rotation competes with bond cleavage.
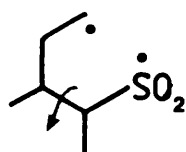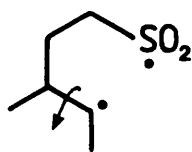
112   **113**

Thermal extrusion of sulphur dioxide from thietan sulphones also proceeds *via* a diradical mechanism; homolysis of the carbon-sulphur bonds to give the 1,3-diradical is followed by ring closure or hydrogen migration. Flash vacuum thermolysis of (108) at 950°C afforded a mixture of cyclopropane and propene[70].

108

In the thermolysis of 2,2-dimethylthietan 1,1-dioxide (114) at the same temperature only a mixture of alkenes was obtained.

114
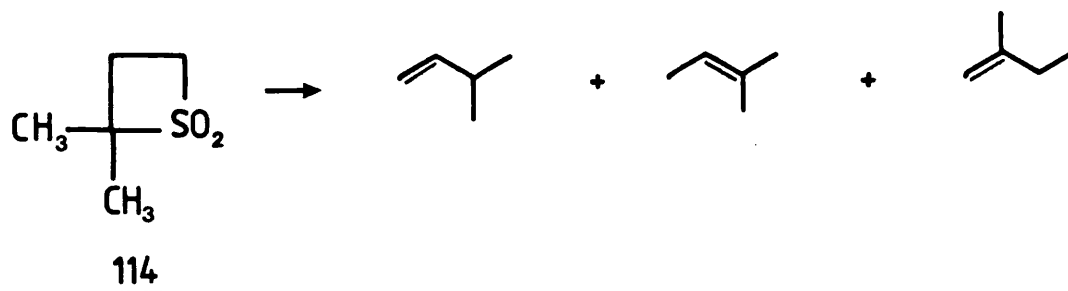
However this does not exclude formation of cyclopropane at some

stage because the ratio of methylbutenes was not dissimilar to that

found by Flowers and Frey in the pyrolysis of 1,1-dimethylcyclopropane[71].

Curiously in the flash vacuum thermolysis of (114) at 800°C a small

amount of the sultine (115) was recovered along with a little of the

starting material.

CH_3 — $S=O$, O, CH_3

115
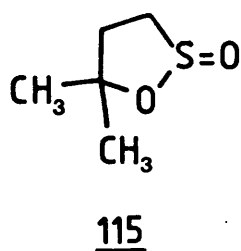
Trost et al[72] studied the thermolysis of cis- and trans-2,4-

dimethylthietan 1,1-dioxide, (116) and (117) respectively.

CH_3 SO_2 CH_3 **116** CH_3 SO_2 CH_3 **117**
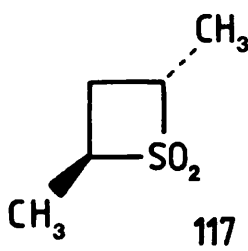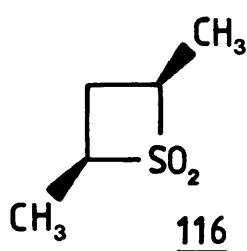
These give mixtures of cis- and trans-cyclopropanes and cis- and

trans-pent-2-enes. The ratio of products is given in Table 3.1, and

the mechanism proposed exemplified by the trans isomer (117) in Scheme

31.

Table 3.1:- <u>Hydrocarbon Products from the Thermolysis of (116) and (117)</u>

Sulphone	trans-cyclopropane (%)	cis-cyclopropane (%)	trans-pent-2-ene (%)	cis-pen-2-ene (%)
116	**40.1**	**33.8**	16.3	9.8
117	**32.9**	**39.2**	16.4	11.5

pent-2-enes

CH_3

Δ

CH_3

CH_3 SO_2

CH_3

117

CH CH_3 H

SO_2

H

118

H CH_3

CH_3 H

conrotary

CH_3 CH_3

CH_3 H

CH_3 CH_3

H SO_2

119

CH_3 CH_3

H H

conrotary

CH_3 CH_3

pent-2-enes
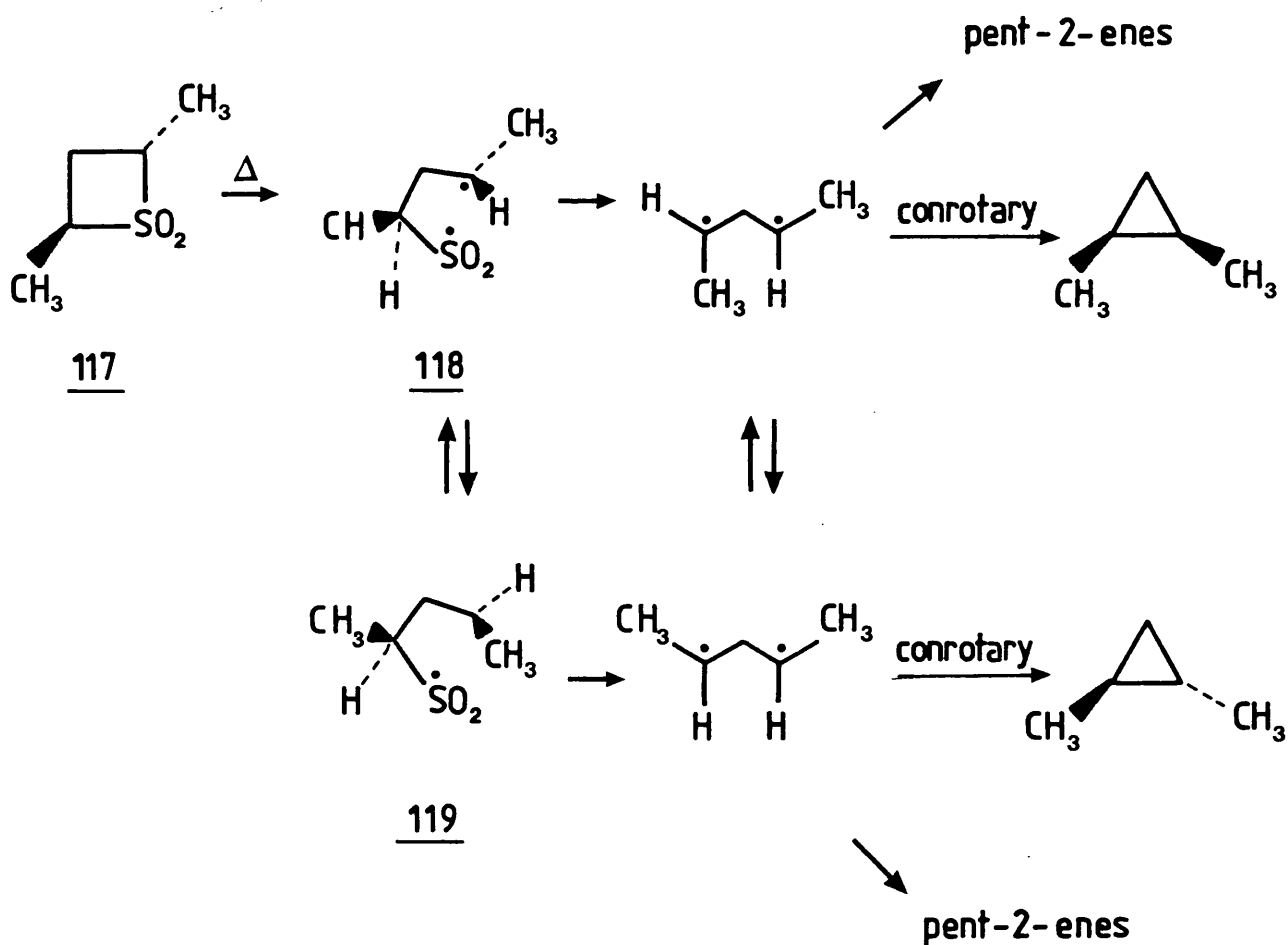
Scheme 31

These thermolyses were carried out at 350°C with contact times much less than one minute.

Table 3.1 shows that there is some degree of memory exhibited in these reactions, and this, combined with the fact that there is no loss of stereochemistry in recovered sulphone, suggests that interconversion of (118) and (119) is slow relative to its decomposition.

Flash vacuum thermolysis of (120) at 770°C gave exclusively the diene (121); this is consistent with a diradical trimethylene intermediate, although a sulphinic acid intermediate cannot be completely ruled out[73].

120   **121**
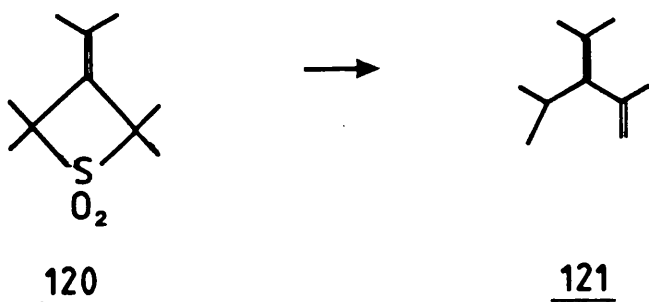
The presence of an α-β double bond within a 4-membered ring sulphone has a dramatic effect. Thiete 1,1-dioxide (122) rearranges to the sultine (124) on heating either in the vapour phase, in solution or under flash vacuum thermolysis conditions[70].

122   **123**   **124**
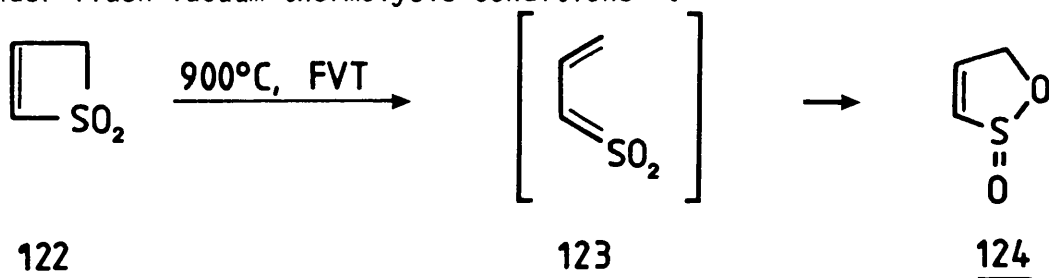
A vinyl sulphene (123) was proposed as an intermediate and efforts were made to trap it. However only phenol gave the desired sulphonic ester (125).

$$\underline{122} \xrightarrow{\Delta} \underline{123} \xrightarrow{C_6H_5OH} \diagup\diagdown^{SO_3C_6H_5}$$

<center>$\underline{125}$</center>
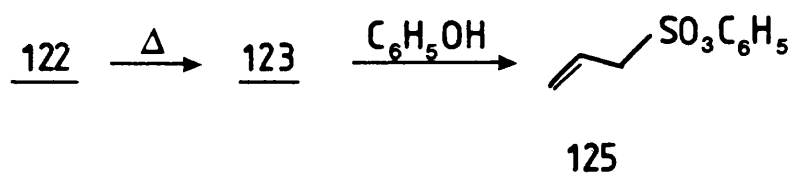
Other attempts to prove the existence of (123) were also largely unsuccessful. The absence of sultines in the thermolysis products of (108) was proposed as evidence that the mechanisms in the thermolysis of (122) and (108) are different and that a diradical intermediate in place of (123) is inappropriate. Later, however, Dittmer et al did successuly trap the intermediate (123), with norbornene[75] (Scheme 32).

$$\underline{122} \xrightarrow{\Delta} \underline{123} \xrightarrow{norbornene}$$
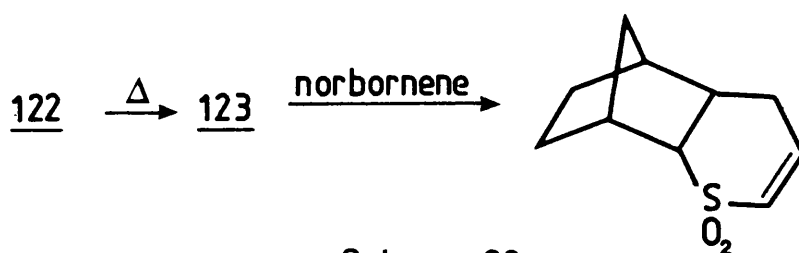
<center><u>Scheme 32</u></center>

Vinyl sulphene has also been implicated in the reaction of propene-3-sulphonyl chloride (126) with triethylamine and methanol[75].

$$CH_2 = CHCH_2SO_2Cl$$

<center>$\underline{126}$</center>
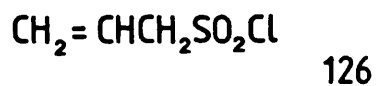
Flash vacuum thermolysis of (122) at 950°C gives propenal[74]; the mechanism proposed is shown in Scheme 33.
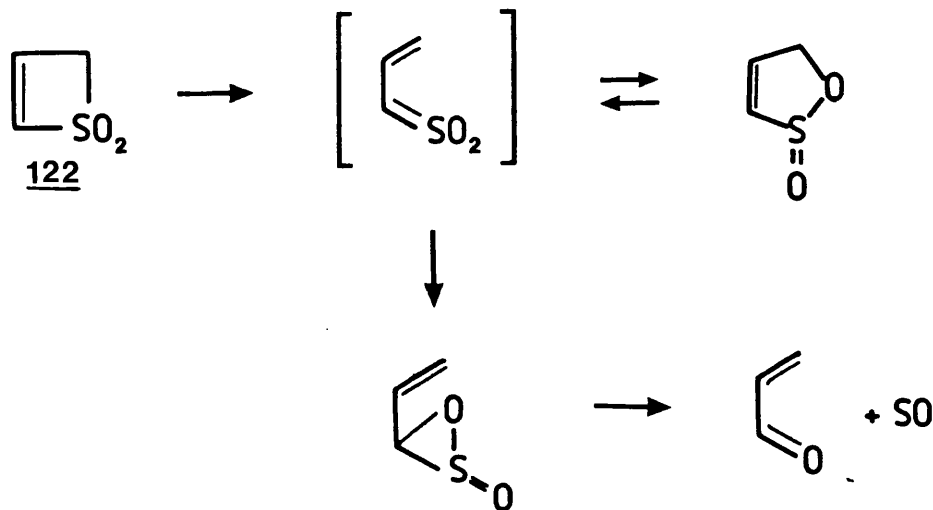
<center><u>Scheme 33</u></center>

The preparation of sultines and α-β unsaturated aldehydes was found to be general for many substituted thiete sulphones[70,77,78] and a further example is given below (Scheme 34). It has been found that higher temperatures generally favour the aldehyde product.
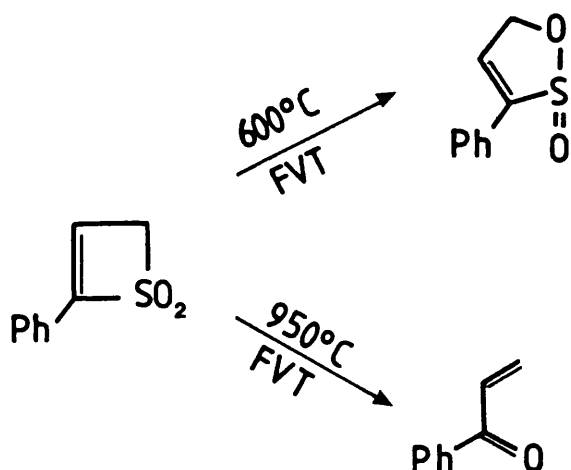
Scheme 34

In the thermolysis of benzo(b) thiete 1,1-dioxide (127), a sultine is again obtained, with a vinyl sulphene again the proposed intermediate[79] (Scheme 35).
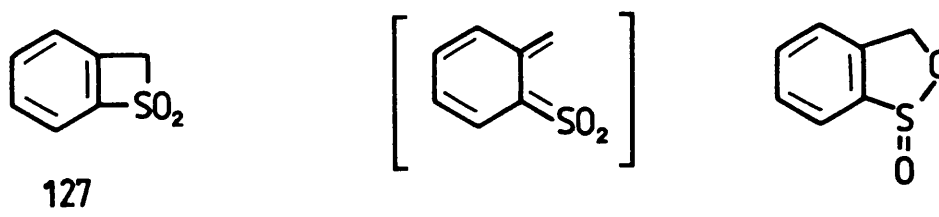
Cope et al heated the allyl sulphone (128) such that partial decomposition was observed (150-250°C, 7.5-1.5 hours)[80], but despite this, (128) was the only compound isolated from the reaction mixture and no sulphinate ester was isolated or detected.

-65-

$$Ph-SO_2-CH_2-CH=CH_2 \qquad Ph-\underset{\underset{O}{\overset{\|}{}}}{S}-O-CH_2-CH=CH_2$$
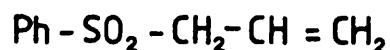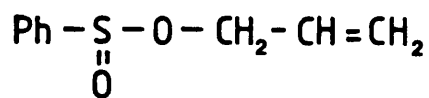
$$\underline{\textbf{128}} \qquad\qquad\qquad \underline{\textbf{129}}$$

However the reverse reaction, converting an allyl sulphinate ester to the sulphone, was observed. Heating (129) at 100°C for 29 hours afforded a mixture of (128) and the starting material.

Heating (130) or (131) under reflux in toluene for 6.5 hours gave the sulphone (132) in low yield. Remaining sulphinate ester was not quantified but instead destroyed by saponification.

$$Ph-\underset{\underset{O}{\overset{\|}{}}}{S}-O-CH_2-CH=CH-CH_3$$

$$\underline{\textbf{130}}$$

$$Ph-SO_2-CH_2-CH=CH-CH_3$$

$$\underline{\textbf{132}}$$

$$Ph-\underset{\underset{O}{\overset{\|}{}}}{S}-O-\underset{\underset{CH_3}{\overset{|}{}}}{CH}-CH=CH_2$$

$$\underline{\textbf{131}}$$
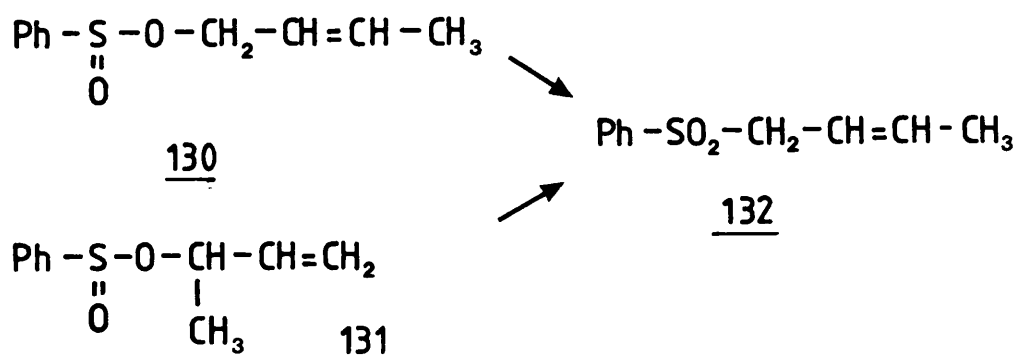
The authors were unsure how to interpret these results.

The flash vacuum thermolysis of some substituted γ-sultines have been undertaken by Finlay[44] and Hall[77]. The extrusion of sulphur dioxide from 3-phenyl-1,2-oxathiolane 2-oxide (133) was observed, followed by ring closure or, at higher temperature, hydrogen shift[81].

600°C

133

750°C

Ph
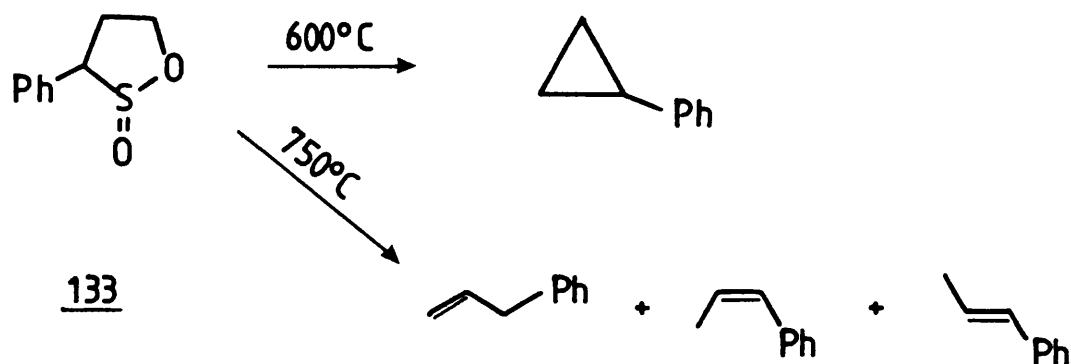
In the pyrolysis of 1-phenyl-1,2-oxathiolane 2-oxide (134), formation of the cyclopropane ring was found to be more favoured[44].

750°C

850°C

134

Ph

Ph Me

Ph

36%   37%   27%
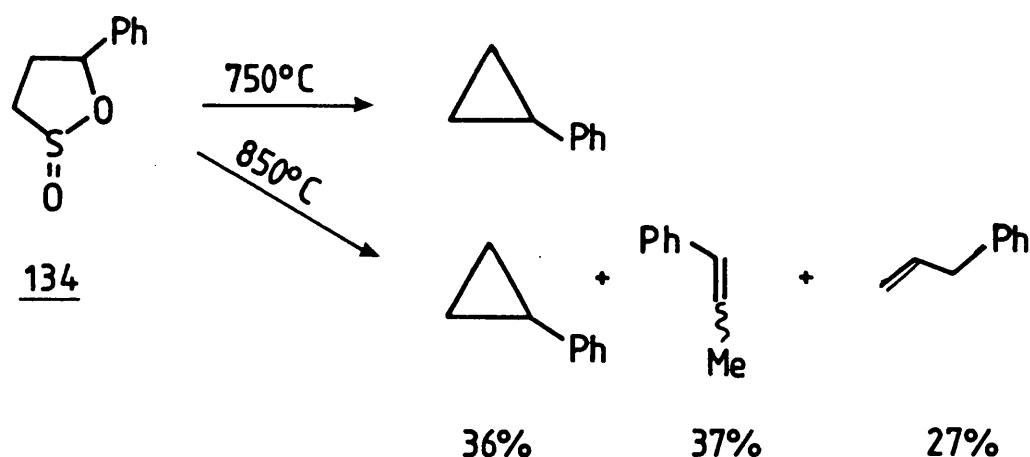
In the absence of a radical stabilising group such as phenyl, higher temperatures were generally required, olefinic products more dominant, and yields reduced, with white polymeric material usually observed in the crude product[44]. An example is given below (Scheme 36).

CH₃

700°C

CH₃

70%   30%
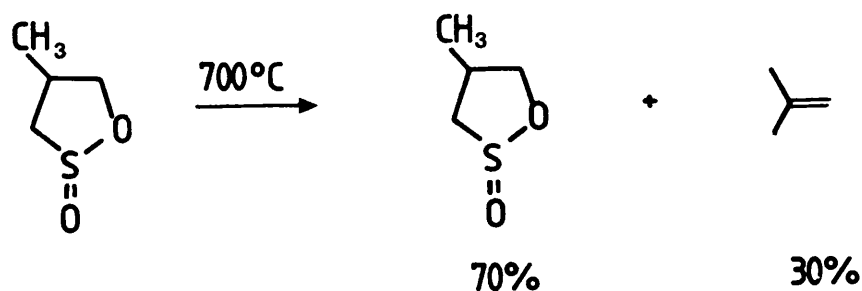
Scheme 36

For all these pyrolyses a two step mechanism is generally supposed, with initial cleavage of the carbon-oxygen bond giving rise to a diradical similar to that proposed for the pyrolyses of thietan sulphones.

A concerted mechanism is however proposed for β-sultines. In the room temperature thermal decomposition of (135), Durst et al observed the retention of stereochemistry, cis-stilbene being the product[82].

__135__
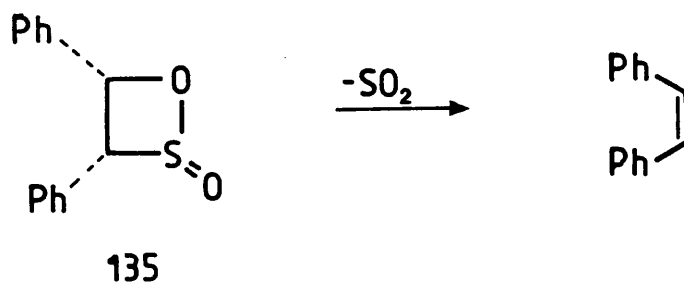
The photolytic behaviour of thietan sulphones has already been described in Chapter Two; sultines behave in a similar manner requiring a chromophore such as phenyl on the carbon bonded to oxygen to allow photochemical **decomposition** [83].

Although thiete sulphones also appear to require an α-chromophore, the photochemical products contrast markedly with those of thietan sulphones. De Schryver has described the photolysis of a number of phenyl substituted thiete sulphones (136)[84] which reacted analogously to Scheme 33.

136
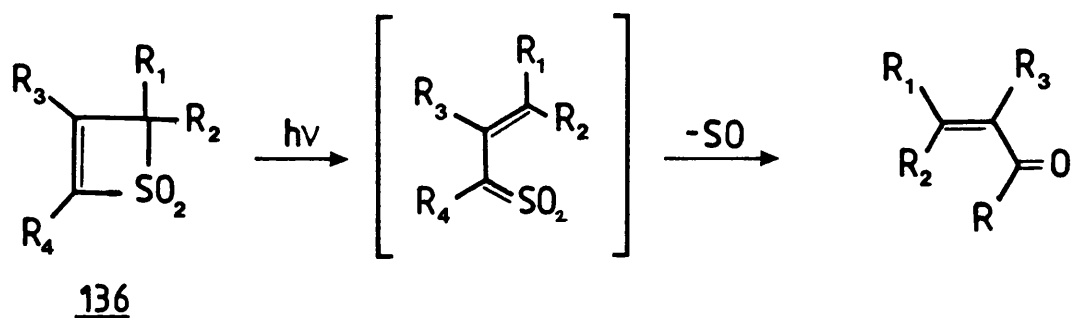
a) $R_1 = Ph$, $R_2 = R_3 = H$, $R_4 = Ph$

b) $R_1 = R_2 = CH_3$, $R_3 = H$, $R_4 = Ph$

c) $R_1 = R_2 = R_3 = H$, $R_4 = Ph$

d) $R_1 = R_2 = H$, $R_3 = OH$, $R_4 = Ph$

e) $R_1 = R_2 = H$, $R_3 = OC_2H_5$, $R_4 = Ph$

3.2   The Synthesis of Chrysanthemates

Of considerable interest in recent years have been the methods of synthesis of trans-chrysanthemic acid (137), owing to the insecticidal activity of some ester derivatives, known as pyrethrins (138).
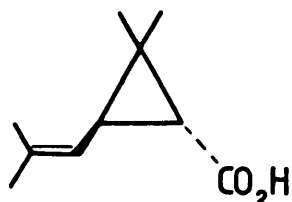
137
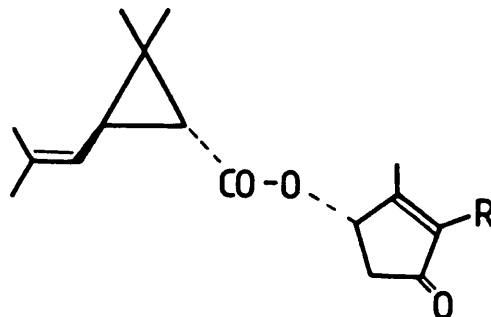
138   R = a cis-olefin chain

A closely related group of compounds based on pyretheric acid replace the trans-vinyl methyl group on the isobutene sidechain with a methoxycarbonyl group. Acids which contain vinyl halide atoms in the isobutene sidechain (139) have also become important synthetic targets, owing to the increased photostability of the resulting pyrethroids.
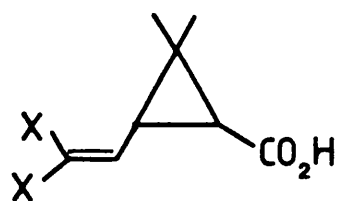
139

a) X = Cl

b) X = Br

The cyclopropyl ring has tended to be the main focus of attention in devising synthetic routes. One of the most common methods has been the addition of a carbene across a double bond, a technique exploited by Aratani et al in the synthesis of optically active trans-chrysanthemate esters[85] (Scheme 37).
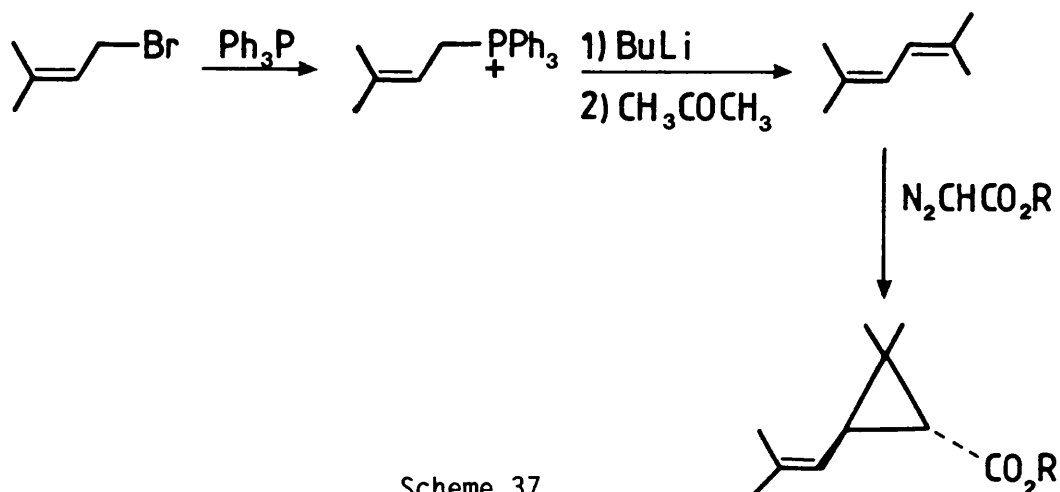
Scheme 37

For further synthesis the reader is referred to other publications[86].

The ability of thietan sulphones to undergo pyrolysis to cyclopropanes invoked the idea they might be possible synthons for the cyclopropyl ring in chrysanthemate esters, and studies based on this idea are described in this chapter. An initial retrosynthetic analysis that ignores stereochemistry is shown in Scheme 38.

X = CH$_3$ or Cl   140   141
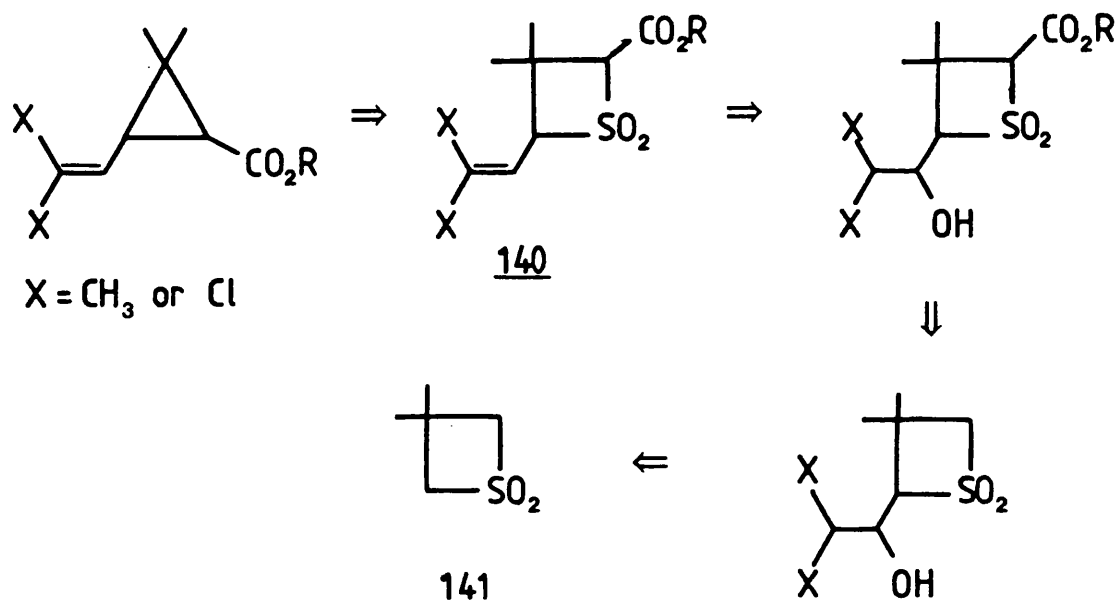
Scheme 38

If such a reaction scheme was to be brought to fruition then it was envisaged that the research would incorporate pyrolysis studies of 2-alkoxycarbonyl-thietan sulphones and 2-(alk-1-ene) thietan sulphones before the attempted pyrolysis of (140). The condensation of 3,3-dimethylthietan 1,1-dioxide (141) with various aldehydes to form hydroxy derivatives would also be studied.

Several methods of preparation of 3,3-dimethylthietan (144), the precursor to the sulphone (141), are described in the literature. These include the preparation of 5,5-dimethyl-1,3-dioxan-2-one (143) from the diol (142)[87] and the treatment of this cyclic carbonate with potassium thiocyanate[88], in an overall yield from diol to thietan of 29%.
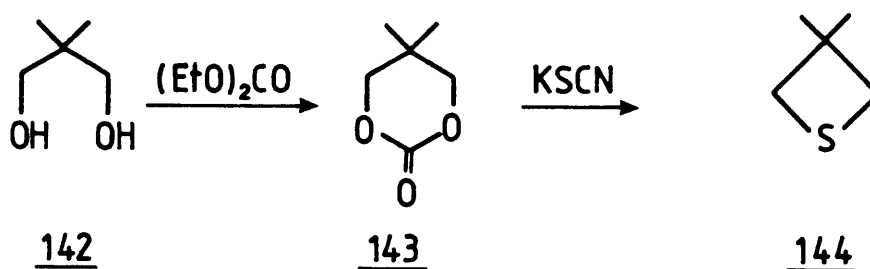
A more efficient method involves the dimesylate (145), which after heating in a dried solution of sodium sulphide in ethanediol gives an overall yield for diol to thietan of over 60%[89].
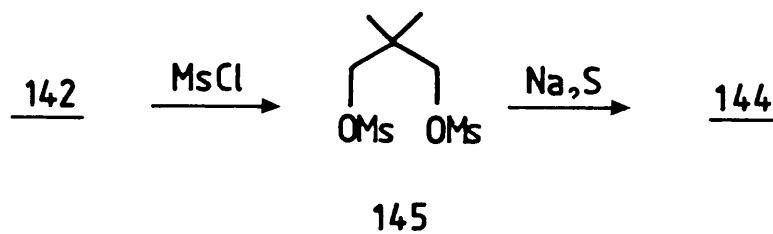
3.3 Description of Flash Vacuum Thermolysis Principles and the Apparatus

Flash vacuum thermolysis involves passing a gaseous stream of the compound under study through a hot tube at low pressure and then trapping the products formed. Occasionally an inert carrier gas is used, although the pressure is still reduced, typically less than 1 mm/Hg[90]. Contact times are very short, usually in the order of 1-20 ms, and are given by Equation 3.1.

$$C.T = \frac{273}{T} \times \frac{V}{22.4} \times \frac{P}{76} \times \frac{t}{m} \qquad (3.1)$$

C.T = Contact Time
P = Pressure (mm/Hg)
V = Volume of Hot Zone (litres)
T = Reaction Temperature (°K)
t = Reaction Time (seconds)
m = No of Moles of Compound

These short contact times allow a significant fraction of the intermediates to emerge from the hot zone, to be condensed onto the cold trap. Hence the cold trap should be situated as close as possible to the end of the hot zone in order to quench any excess energy of surviving intermediates and prevent further reaction. The number of collisions in the hot zone can be minimised by keeping the pressure as low as possible, using a small hot zone, and subliming or vapourising the compound into the hot zone at a slow steady rate.

For preparative reactions the temperature of the hot zone should be kept as low as possible, consistent with a reasonable yield.

The apparatus used in this work is shown in Figure 3.1. The hot zone is 10 cm long, the end of which is approximately 1.3 cm away from the surface of the cold finger, which was cooled with liquid nitrogen. The whole apparatus is made of quartz with the exception of the cold finger.

In a typical run, the apparatus was connected to an oil diffusion pump and evacuated to 5×10^{-3} mm/Hg, as read by a McLeod gauge positioned between the trap and the pump (this did not therefore give an accurate measurement of the pressure in the hot zone). The temperature of the hot zone was controlled with a variac and monitored using a thermocouple connected to a digital thermometer. The thermocouple was inserted between the wall of the furnace and the quartz tube, such that it just reached the mid-point of the hot zone. The sample (typically about 120 mgs), was contained in a round bottom flask fixed at 'B'
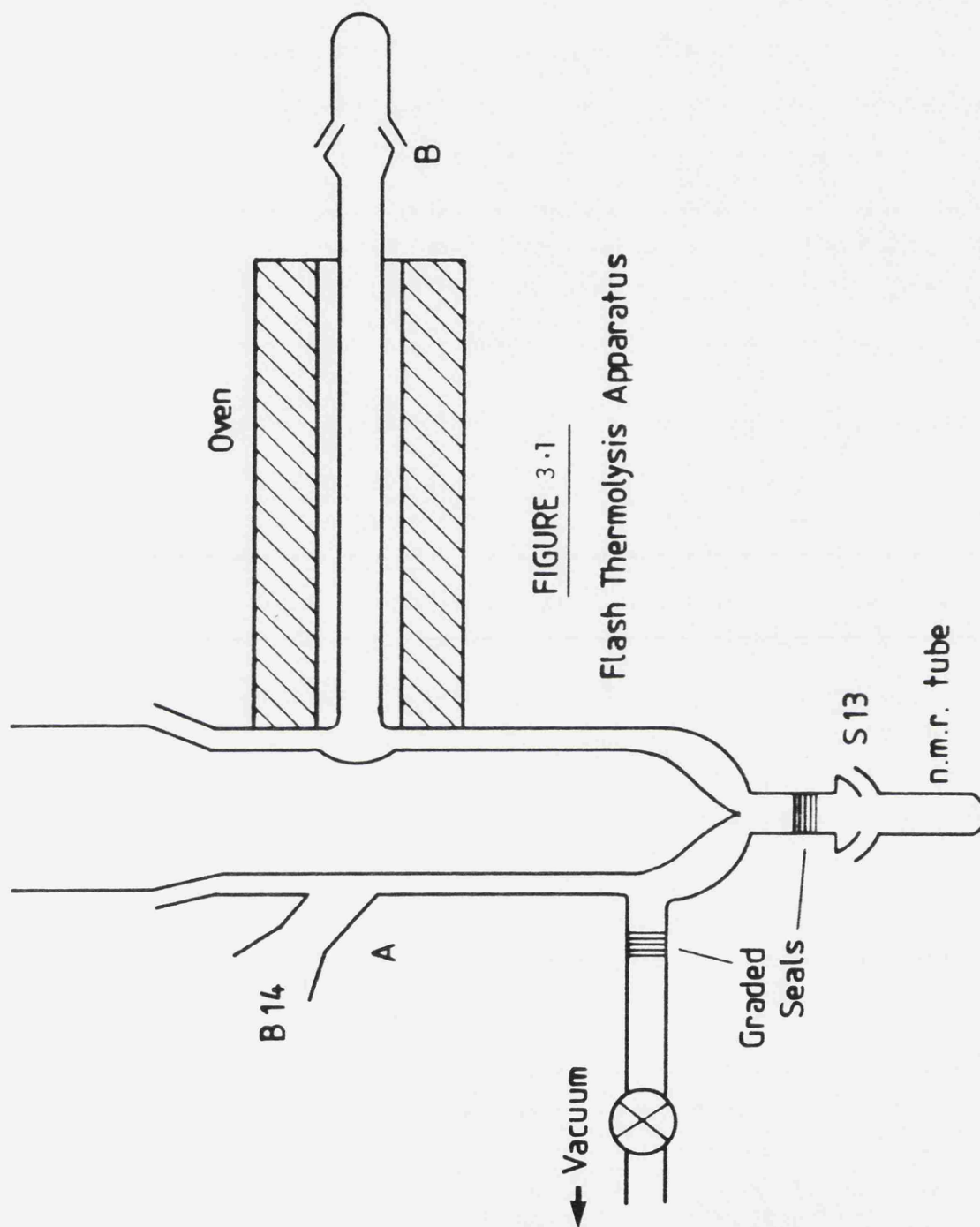
FIGURE 3·1

Flash Thermolysis Apparatus

and was sublimed through the apparatus at a rate of about 0.1g h^{-1}, using a Kugel oven placed around the flask. The products would condense in the dimple of the cold finger.

When sublimation was complete the furnace was switched off and the system flushed with dry nitrogen. The cold finger was turned in its joint such that the dimple was facing inlet port 'A', and, when the trap had nearly warmed to room temperature, a solvent was introduced to wash the products into the n.m.r. tube below.

3.4   Preparation of 3,3-Dimethylthietan and its Dioxide

The ditosylate (146) can be prepared almost quantitatively from the diol (142)[91].

Heating (146) in a dried solution of sodium sulphide in ethanediol afforded the thietan in yields ranging from 60-68%. This does not represent an improvement in the step from disulphonate ester to thietan (Newman et al recorded a 69% yield for the dimesylate[89]), but the ditosylate was found to be easier to prepare and gave a purer product. This trivial change was adopted for all preparations of 3,3-dimethylthietan.

$$\underline{142} \quad \xrightarrow[\text{pyridine}]{\text{TsCl}} \quad \underset{\underset{\underline{146}}{\text{OTs OTs}}}{\bigvee} \quad \xrightarrow{\text{Na}_2\text{S}} \quad \underline{144}$$
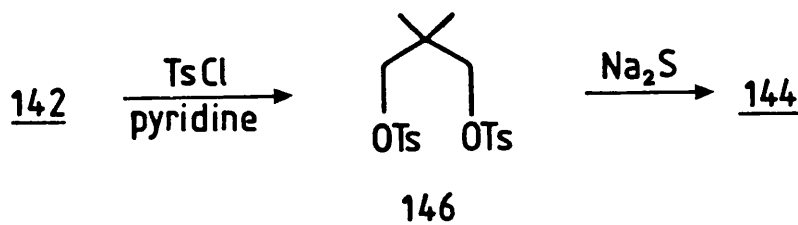
The sulphone was prepared in high yield from the thietan by oxidation using m-chloroperbenzoic acid.

3.5 Preparation of 2-(1-Hydroxyalkyl)3,3-dimethylthietan 1,1-dioxides

Treatment of (141) in THF with a slight excess of n-butyl-lithium at -78°C followed by addition of an aldehyde gave the alkylated derivatives (147).

141   **147**

a) $R = (CH_3)_2CH$

b) $R = CCl_3$

c) $R = CHCl_2$
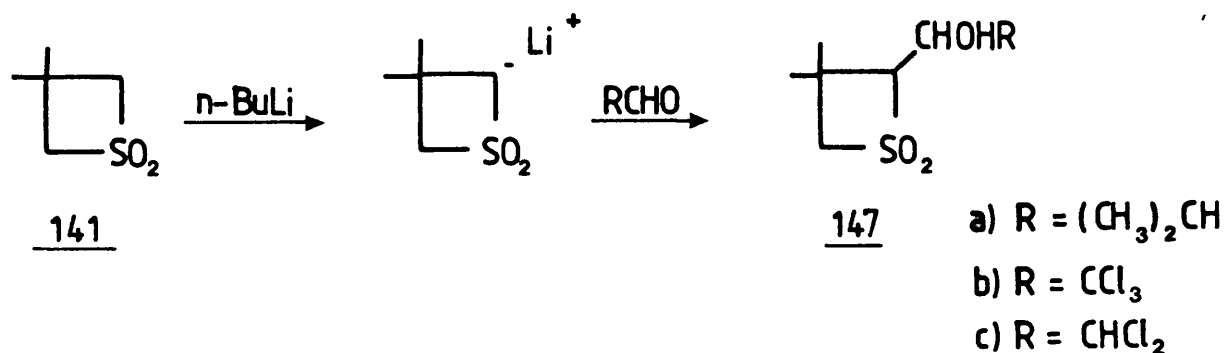
Table 3.2:- Preparation of Substituted 3,3-Dimethylthietan
1,1-dioxides (147), using n-BuLi at 78°C

Aldehyde	Product	Yield (%)
$(CH_3)_2CHO$	147 (a)	34
CCl_3CHO	147 (b)	30
$CHCl_2CHO$	147 (c)	15-33

Also along with 34% yield of 147 (a), the diol (148) was also isolated in 9% yield.

148
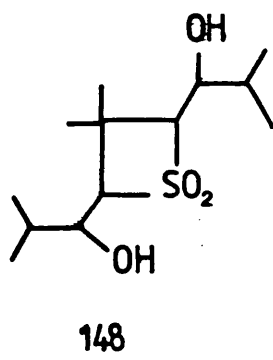
Separation of the two compounds (147a) and (148) from each other was difficult and could only be achieved by the use of a precise and efficient chromatography column. No diol was isolated in the preparation of (147b) and (147c).

Incorporation of HMPT (see Section 1.8) into the reaction mixture gave no improvement in yield, and indeed served only to reduce it.

The use of ether as the solvent instead of THF (see Section 2.4) led to a slight reduction in the yield of (147a) (23-27%). In this case the fact that the sulphone was reacted mainly as a suspension in ether but entirely as a solute in THF may have influenced the difference in yields but too many unexamined variables existed to allow definite conclusions to be drawn.

Although yields are not good, clearly alkylation of (141) can be successfully accomplished, in contrast to the behaviour of thietan 1,1-dioxide (108) and 2-methoxycarbonyl-2-phenylthietan 1,1-dioxide (104) which gave only decomposition products under the same conditions. This latter phenomenon was discussed in Section 2.8, and the proposal made that in the attempted alkylation of (108) and (104), β-hydrogen attack occurs. The fact that (141), which contains no β-hydrogens, can be successfully alkylated lends considerable weight to this proposal.

3.6 Preparation of 2-(2-Methylpropan-1-ol)3,3-dimethylthietan 1,1-dioxide Derivatives

Wendler et al[92] prepared the dimesylate of a diol, where both hydroxy groups were secondary, by treating a solution of the diol in pyridine with excess methanesulphonyl chloride and allowing to stand at 0-5°C for 16 hours. Similar treatment of (147a) failed to yield any of the desired mesylate (149). It was found that (149) could be obtained by treating a solution of (147a) in pyridine with a large excess of methanesulphonyl chloride and allowing to stand at slightly higher temperatures (room temperature initially then 30-40°C).
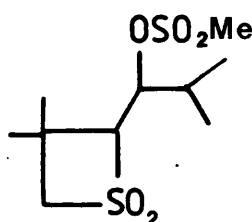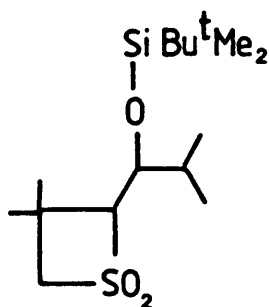
149   150

The silyl ether (150) also proved difficult to prepare. Ordinarily silyl ethers can be prepared under fairly mild conditions. A reaction mixture of t-butyldimethylsilyl chloride, imidazole and an alcohol in dimethyl formamide kept at 35°C for ten hours was found to give the silyl ether in very high yield[93]. The conditions required for the preparation of (150) were found to be more vigorous and prolonged. The reaction mixture was stirred initially at room temperature for approximately nine days and then at 50-60°C for a week. At the end of this period the starting hydroxysulphone was still detectable; work up afforded a 48% yield of (150).

Clearly (147a) is a very hindered alcohol, with a secondary hydroxy group flanked by two tertiary carbon centres. However a further factor could help explain the unreactivity of this hydroxy group. Kotin found that the hydroxy group in (151) was also considerably unreactive, and proposed that the compound was adopting a six-membered ring geometry that involved hydrogen bonding between the hydroxy hydrogen and the sulphonyl oxygen[66].

151
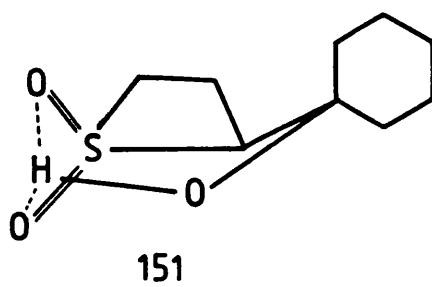
Compound (147a) could adopt a similar geometry. However spectral evidence for this is poor. The infrared absorbtion band for the hydroxy group was at 3600 cm^{-1}, suggesting that hydrogen bonding was either very weak or non-existent. All n.m.r. spectra of (147a) showed a doublet for the hydroxy function, but this probably indicates high sample purity rather than intramolecular hydrogen bonding.

3.7   Methods of Preparation of 2-(alk-1-enyl)thietan 1,1-dioxides

Using the alcohol (147a) as starting material, a number of dehydrating agents were used in an effort to prepare the alkene (152), whose thermolysis behaviour was expected to be of interest.

147a ⟶

152

-79-
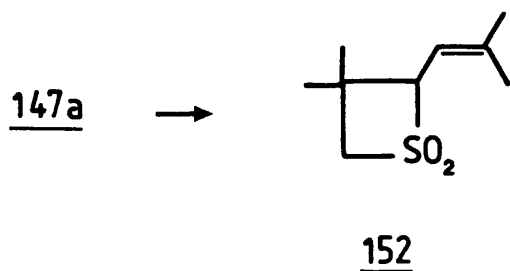
Initially it was believed that generation of a carbonium ion α

to a four-membered ring might bring about ring expansion or opening,

and a method with a mechanism as close as possible to E2 was desired.

The elimination of methanesulphonic acid from a sulphonate ester is a

method generally recognised as such; however, treatment of the

sulphonate ester (149) with 1,5-diazabicyclo[5,4,0]undecene-5 in THF,

heated under reflux, afforded a mixture of two compounds. Both had

very similar physical properties. They were inseparable by distillation

and had very similar reference values on t.l.c. Infrared spectroscopy

suggested the presence of sulphonyl and possibly olefinic groups, but

no other functional groups were implicated. It was therefore suspected

that the product was a mixture of the alkenes (152) and (153), but it

was necessary to synthesise one or both of these alkenes to confirm

this.
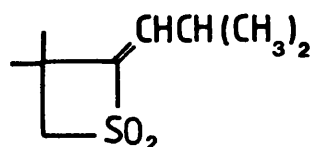
153

On the supposition that an 'E2' mechanism had given a compound with

a double bond fused to the ring, a series of dehydrating agents that

involved the generation of a carbonium ion were tried.

Heating (147a) in polyphosphoric acid gave a mixture of the starting

material and decomposition products.

Potassium bisulphate has also been previously used as a dehydrating

agent[94]. The hydroxy sulphone was mixed and ground with excess potassium

bisulphate and heated at 220°C for eight hours; work up gave only the

starting material.

Anhydrous copper sulphate has been found to be a more effective dehydrating agent, with a recommended reaction temperature of 160-180°C for secondary alcohols[95]. However, when (147a) was mixed and ground with anhydrous copper sulphate and heated to either 170°C or 220°C, a black solid was recovered which was identified as starting material by n.m.r. spectroscopy. Once again (147a) appears to have a very unreactive hydroxy group.

Treatment of a stirred solution of (147a) in pyridine with thionyl chloride at 0°C followed by stirring overnight at room temperature afforded a mixture of two compounds. The major component was isolated in low yield by distillation and identified as (152). The n.m.r. spectrum of the residue was consistent with the structure (154), although other analytical methods were unable to confirm this.

154
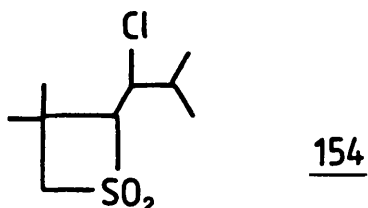
Stirring a solution of the crude product mixture in pyridine for a further two days caused no change in the n.m.r. spectrum, therefore indicating that elimination occurs from the chlorosulphite intermediate only, and not from (154), assuming the latter to be present.

In an attempt to obtain (152) in better yield a similar reagent, phosphoryl chloride, was tried. Treatment of a solution of (147a) in dry pyridine with a slight excess of phosphoryl chloride at 0°C, followed by stirring overnight at room temperature gave the alkene (152) in 41-44% yield.

The isolation of (152) allowed the mixture suspected of being (152) and (153) to be studied in greater detail. The n.m.r. spectrum of pure (152) in deuterochloroform is described in Figure 3.2.

δ1·28,s H$_3$C   Hδ4·77, d, J=10Hz   CH$_3$ δ1·81,s

δ1·37,s H$_3$C —————————— CH =
                     δ5·35,d   CH$_3$ δ1·82,s
                     J=10Hz

δ3·78,d, J=13Hz H ——————— SO$_2$

δ3·58,d, J= 13Hz H
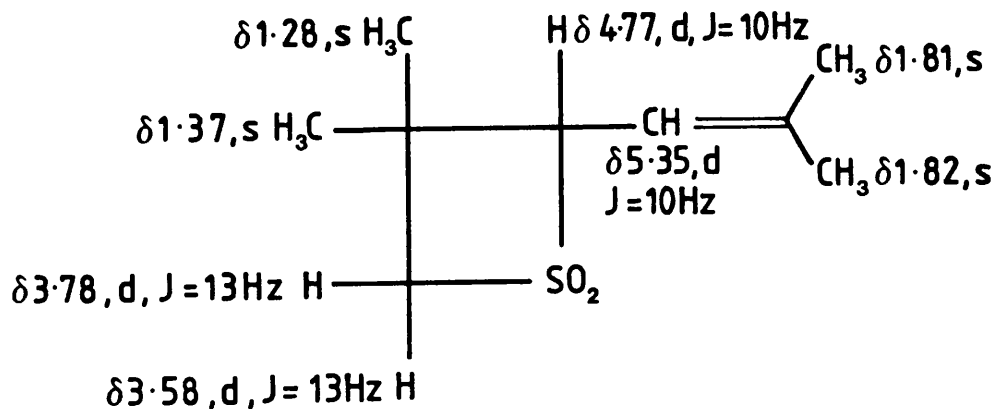
Figure 3·2

These peaks were present in the n.m.r. spectrum of the mixture in question, although their integration clearly showed that (152) was the minor component. Subtracting these peaks from the spectum, the remainder approximated to: δ(CDCl$_3$) 5.57 (H,d,J=12Hz), 3.67 (2H,s), 3.00-2.65 (1H,m), 1.34 (6H,s), 1.10 (6H,d,J=7Hz).

These peaks appear to be consistent with the structure (153), with each [1]H n.m.r. signal attributable to a particular hydrogen or group (Figure 3.3). The fusion of the double bond to the ring produces a symmetry about the plane of the ring which results in the two ring methyl groups being equivalent, as are the two ring hydrogens. These were not equivalent in any other 3,3-dimethylthietan sulphone derivative containing one extra group bonded to the ring in addition to the two ring methyls.

<p style="text-align:center">CH_3 δ 1·10, δ, J = 7Hz
H δ 3·00-2·65, m
CH_3 δ 1·10, d, J = 7Hz
H δ 5·57, d, J = 12Hz</p>

δ 1·34, s, CH_3

δ 1·34, s, H_3C

δ 3·67, s, H —— SO_2

δ 3·67, s, H
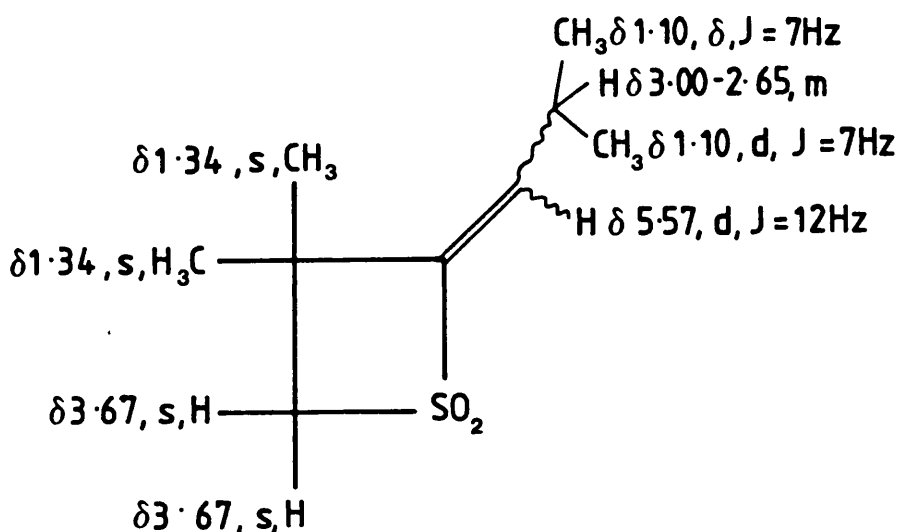
Figure 3·3

Froemsdorf and McCain[96] studied the elimination of p-toluene-sulphonic acid from 2 p-toluenesulphonyloxy substituted alkanes in dimethyl sulphoxide (DMSO) and found that 1-enes predominated. Taking into account other data which eliminated the possibility of cis-elimination, they concluded that the data were 'consistent with a trans-elimination, with a transition state that involves a great deal of heterolysis of the carbon-hydrogen bond and a lesser amount of heterolysis of the carbon-oxygen bond'. Hence the acidity of the hydrogen lost in this reaction becomes a more important factor than in other eliminations and the competition between the formation of (152) and (153) reflects the influence of the acidity of the ring hydrogen and the steric strain the ring imposes on the transition state in the formation of (153).

Treatment of a solution of (147c) in pyridine with phosphoryl chloride gave the expected product (155).

$\underline{147c} \longrightarrow$ **155**
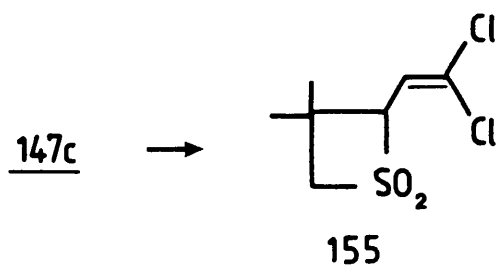
In order to prepare (155) from (147b) an attempt was made to prepare the epoxide (156).

156
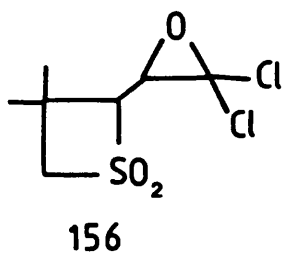
The use of α-chlorohydrins in the preparation of epoxides is well reported[97]. The reaction of alkoxides with chloroform to form trialkyl orthoformates is known, the reaction almost certainly proceeding via dichlorocarbene[98]; the analogous reaction of chloroform with phenoxides gives triaryl orthoformates in poor yield[99]. Benzotrichloride and substituted benzotrichlorides have been reported as reacting with alcoholic alkoxides to form trialkyl orthobenzoates[100] and other trihalomethyl compounds lacking an α-hydrogen may also give ortho esters on similar treatment; for example hexachloropropene has been converted to triethyl-2,3,3-trichloroorthoacrylate on reaction with ethoxide[101]. However, in the case of trichlorohydrins the preparation of dichloroepoxides by this or any other method has remained unreported.

Treatment of a solution of (147b) in dry ethanol with sodium
hydroxide and gradual warming caused precipitation when the boiling
point was reached. No starting material or desired product was
isolated from the reaction mixture. Treatment of (147b) in dry DMSO
with sodium hydride followed by a very gradual warming to 90°C afforded
starting material and a number of decomposition products. Incorporation
of silver nitrate into the reaction mixture caused no appreciable
change in the behaviour of the reaction.

In an attempt to dehydrate the diol (148), the previously successful
reagent, phosphoryl chloride, was used. However when a solution of
(148) in pyridine was stirred overnight at room temperature with
phosphoryl chloride, the only product was the chloride (157), isolated
in low yield. The presence of chlorine was clearly indicated in the
mass spectrum by peaks at m/e 255 and m/e 253, representing loss of
an isopropyl group from (157). The n.m.r. spectrum, though complex,
was consistent with structure (157). None of the expected alkene was
detected.

148 ⟶
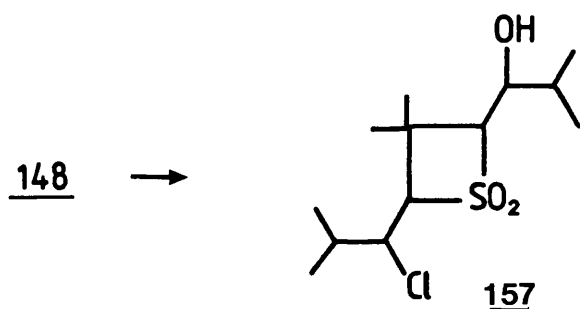
Clearly in the above reaction the second hydroxy group interfered
in the reaction of the first. Evidence for the ability of these two
groups to interact comes from the I.R. spectrum of (148). This shows
two sharp bands, including one at 3540 cm^{-1}, thus indicating
intramolecular hydrogen bonding. The ^{1}H n.m.r. spectrum was also
unusual in that it showed a broad singlet for the hydroxy hydrogen,
as opposed to the doublets observed for (147a), (147c) and (157).

3.8 Preparation of 2-Methoxycarbonyl-3,3-dimethylthietan 1,1-dioxides

The anion of the sulphone (141) was generated by treating a solution of (141) in THF with n-butyl- lithium at -78°C. When dry carbon dioxide was bubbled through, a precipitate was immediately formed, which was isolated and acidified to give the crude acid (158). Recrystallisation gave the pure acid in only 18% yield but considerable crude acid remained which, although it could not be recrystallised, was considered suitable for esterification. Treatment of the pure acid with diazomethane gave the methyl ester (159) in 72% yield. The reaction Scheme is summarised in (Scheme 39).

$$\underline{141} \longrightarrow \overset{\text{-Li}^+}{\underset{\text{SO}_2}{\Box}} \longrightarrow \overset{\text{CO}_2\text{H}}{\underset{\text{SO}_2}{\Box}} \longrightarrow \overset{\text{CO}_2\text{Me}}{\underset{\text{SO}_2}{\Box}}$$

Scheme 39

$$\underline{158} \qquad \underline{159}$$
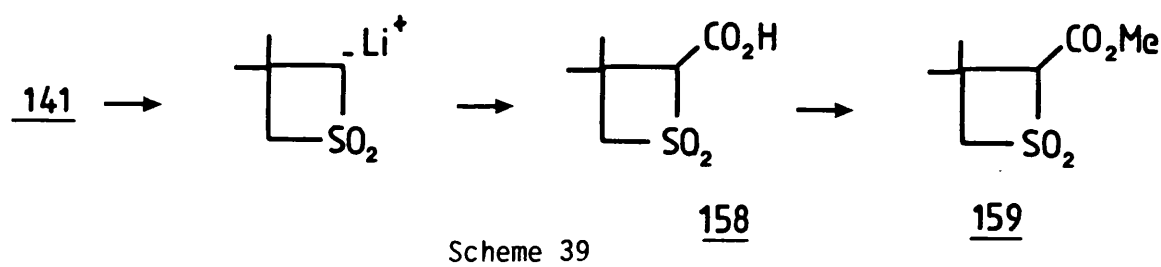
Esterification of the crude acid with the same reagent gave the same crude methyl ester (159) but which could not be recrystallised. Flash chromatography, while removing some impurities, gave rise to a mixture of (159) and (141). The presence of (141) is clearly the result of decomposition of (159):none was present in the crude acid product, and the pure methyl ester gave one spot on analysis by t.l.c., with a reference value corresponding to that of (141). The mixture of (159) and (141) also gave one spot, again with the same reference value. The presence of only two compounds, both known, allowed the calculation of their relative amounts by n.m.r. spectroscopy, and this in turn gave a figure for the overall conversion of (141) to (159) in Scheme 39 of 60%.

A solution of (147a) in THF at -78°C was treated with a 2.1 equivalent
of n-butyl-lithium. Dry carbon dioxide was bubbled through, causing
an immediate precipitation, and acid work up gave the crude acid
(160). Recrystallisation was unsuccessful but treatment with
diazomethane follwed by recrystallisation gave the ester (161).
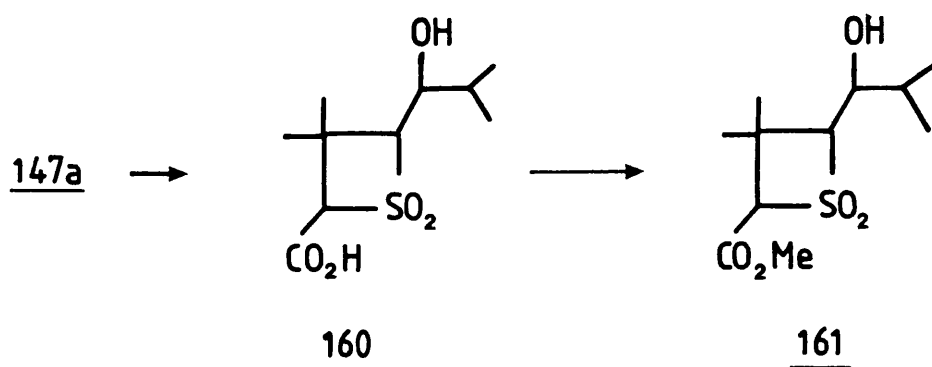
Compound (161) gave one spot on analysis by t.l.c. with a reference
value corresponding to that of (147a).

Repeated attempts to carboxylate the sulphone (147c) were unsuccessful.
Addition of n-butyl-lithium to a solution of (147c) in THF at -78°C
caused immediate precipitation and, after bubbling through carbon
dioxide, only decomposition products were found. None of the desired
compound (162) was isolated. The use of lithium diisopropylamine
instead of n-butyl-lithium did not cause precipitation. However
after bubbling dry carbon dioxide through the reaction mixture,
followed by acidic work up, the only compound isolated or identified
was the starting alcohol.

OH
|—CHCl$_2$
—SO$_2$

147c

—X⟶

OH
|—CHCl$_2$
—SO$_2$
CO$_2$H

162
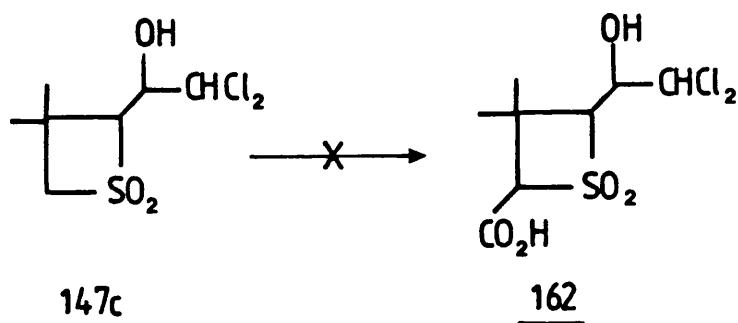
3.9   The Stability of α-Alkoxycarbonyl Sulphones During Chromatography

All the α-sulphonyl esters prepared in the course of this research,

(102), (104), (159) and (161) were observed to lose their alkoxycarbonyl

group during thin layer or column chromatography and revert to the

non-carboxylated sulphones from which they had previously been

prepared.   This is not a phenomenon that appears to have been previously

reported.

The fact that the esters (159) and (161) gave spots on t.l.c. that

corresponded to those of the analogous non-carboxylated sulphones ie,

(141) and (147a) respectively, suggests that this is a rapid process.

In eluting crude (102) through a column of alumina, it was observed

that the ester was collected from the column before the non-carboxylated

sulphone (89).   This can be explained by the suggestion that the

decomposition involves an intermediate which is more polar than the

ester.

The decomposition also necessitates a reaction scheme where the

rate determining step involves the cleavage of the carbon-carbon bond

that is broken in order to explain the fact that while the alkoxycarbonyl

group is lost here, esters are usually stable to chromatography.

Only this cleavage is likely to be influenced by the presence of the

sulphonyl group. One possible reaction mechanism could be nucleophilic

attack at the alkyl group of the ester. This would also involve

extrusion of carbon dioxide and possibly a sulphonyl anion intermediate

(Scheme 40).
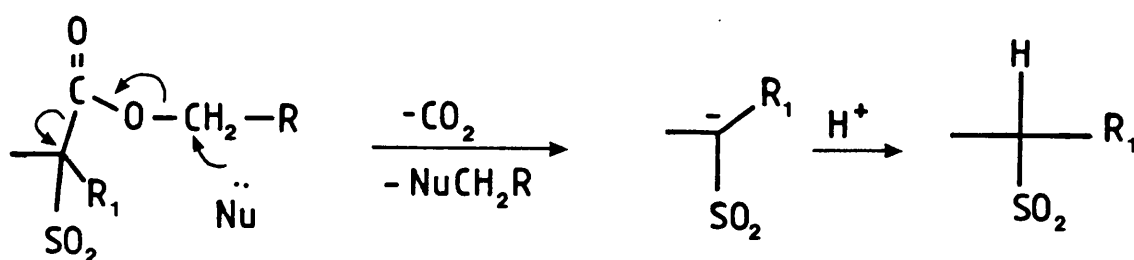
Scheme 40

3.10 Preparation of Sulphone (163)

The alcohol (161) and phosphoryl chloride (0.6 equivalent) in

pyridine were mixed together at 0°C and stirred for four hours at

room temperature. Work up gave an oil which would not crystallise,

even after distillation.

Allowing for impurities the n.m.r. was consistent with that expected

for (163).
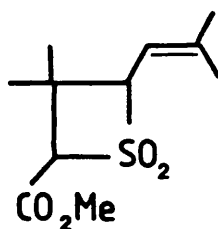
163

In order to conform with the behaviour of other sulphonyl esters, (163) was expected to correspond on t.l.c. with its decarboxylated analogue (152). This proved to be the case, with the only other detectable compound corresponding to the sultine (164), a compound that was being prepared simultaneously in a separate experiment.
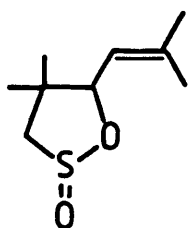
164

The temperature needed to observe any peaks on analysis by g.l.c. proved too high and resulted in decomposition. The mass spectrum showed a peak at m/e 246, the correct molecular weight, but with the dominant peak at m/e 182, corresponding to loss of sulphur dioxide.

3.11 Pyrolysis of 3,3-Dimethyl-2-methoxycarbonylthietan 1,1-dioxide

Flash vacuum thermolysis of the sulphone (159) at 750°C gave the corresponding cyclopropyl ester (165).

159   **165**
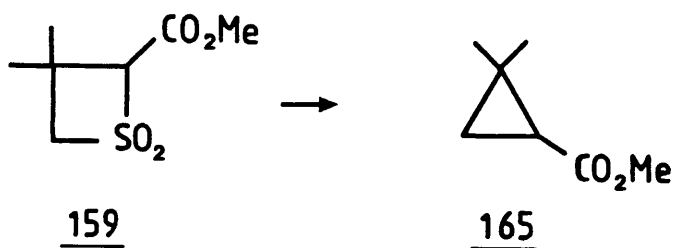
Analysis by n.m.r. spectroscopy and t.l.c. revealed that none of
the starting material was present in the crude product, and g.l.c.
analysis showed that there was one dominant volatile compound.
However, distillation caused decomposition into a second unidentified
product. A sample of the cyclopropyl ester was eventually obtained
in much reduced yield by preparative g.l.c. and was identified by
comparison with a published n.m.r. spectrum[102].

Flash vacuum thermolysis of (159) at 675°C gave a mixture of (165)
and the starting material. Calculation of the amounts present by
n.m.r. spectroscopy gave a 69% yield of (165) from reacted starting
material.

Photolysis of (159) at 254 nm resulted in a nearly quantitative
recovery of the starting material. None of the cyclopropane (165)
was detectable.

152   164
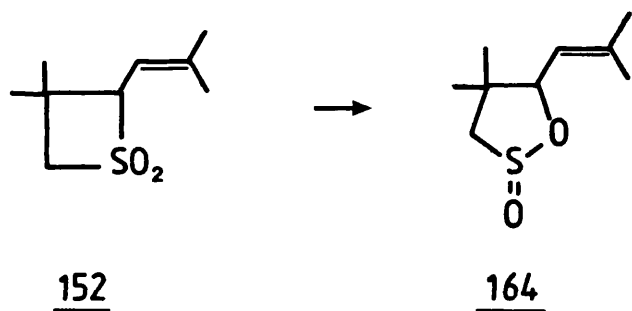
3.12 Pyrolysis of 2-(Alk-1-enyl)-3,3-dimethylthietan 1,1-dioxides

Flash vacuum thermolysis of the allylic sulphone (152) at 700°C
gave a mixture of the starting sulphone and the sultine (164), which
were separated by column chromatography.

The sultine (164) was in turn a mixture of diastereoisomers, g.l.c.
analysis indicating the presence of two compounds. The n.m.r. spectrum
was consistent with two diastereoisomers of (164), showing four peaks
for both the ring methyl and vinyl methyl groups. The average chemical
shift of the ring methyls was approximately δ1.1, representing a drop

in comparison with the sulphone (152) of about $\delta 0.2$, which would be

consistent with a relief in ring strain. The two ring hydrogens

adjacent to the sulphur form doublets of doublets in both diastereoisomers,

with coupling approximately 12Hz. In the minor isomer the chemical

shift values for these two hydrogens are very close together at $\delta 3.10$

and $\delta 2.90$ and exhibit the familiar pattern associated with doublets of

doublets. However, in the major isomer the line perturbation is less

pronounced owing to the hydrogens being much more widely split at

$\delta 3.50$ and $\delta 2.72$.

The presence of a strong band in the infrared spectrum at 1120 cm^{-1}

with none between 1350 cm^{-1} and 1310 cm^{-1} confirmed that a sulphinate

ester was present rather than a sulphone and the only other functionality

implicated was olefinic by a band at 1674 cm^{-1}. The mass spectrum

gave m/e 189 as the molecular ion, presumably due to protonation

of the ring oxygen.

The yield of the sultine was low, but a considerable amount of

white polymeric material was also present in the crude product.

Flash vacuum thermolysis at 900°C resulted in the isolation of no

identifiable compounds, the vast majority of the crude product

consisting of insoluble blackened material.

Photolysis of (152) at 254 nm gave a mixture of starting material

and decomposition products.

Flash vacuum thermolysis of (155) at 700°C gave a mixture of starting

material and the sultine (166).
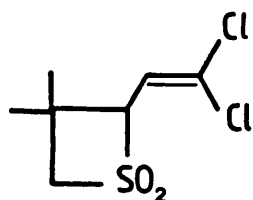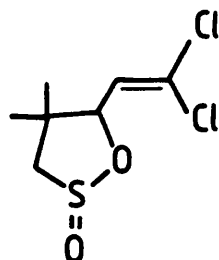
155   **166**

The yield was again poor with a considerable amount of white
polymeric material isolated, along with products that remained on the
baseline during t.l.c. analysis. The relative amounts of sulphone
and sultine are given in Table 3.3.

Table 3.3:-   Products from the Thermolysis of (152) and (155)

Sulphone	Temp. °C	% Sultine	% Sulphone
152	700	72	28
152	900	-	-
155	700	74	26

The isolation of sultines as the major products and the non-isolation
of cyclopropyl derivatives must be regarded as a surprising result.
The pyrolytic behaviour of (152) and (155) was expected to imitate
that of other thietan sulphones which normally extrude sulphur dioxide.
However precedents for the isolation of a sultine from thermolysis of
a ring sulphone do exist, and the introduction to this chapter
included the examples given by King et al[74], whose research concentrated

-93-

on the thermolytic preparation of 5H-1,2-oxathiole 2-oxide (124) from thiete 1,1-dioxide (122).

Clearly the mechanism for formation of (164) and (166) necessitates initial cleavage of the allylic sulphur-carbon bond to give the diradical resonance structures (167) and (168), with subsequent ring closure to the sultine.

a) <u>152</u>

b) <u>154</u> $\longrightarrow$

a) <u>164</u>

b) <u>166</u>

167

168

a) X = CH$_3$

a) X = CH$_3$

b) X = Cl

b) X = Cl
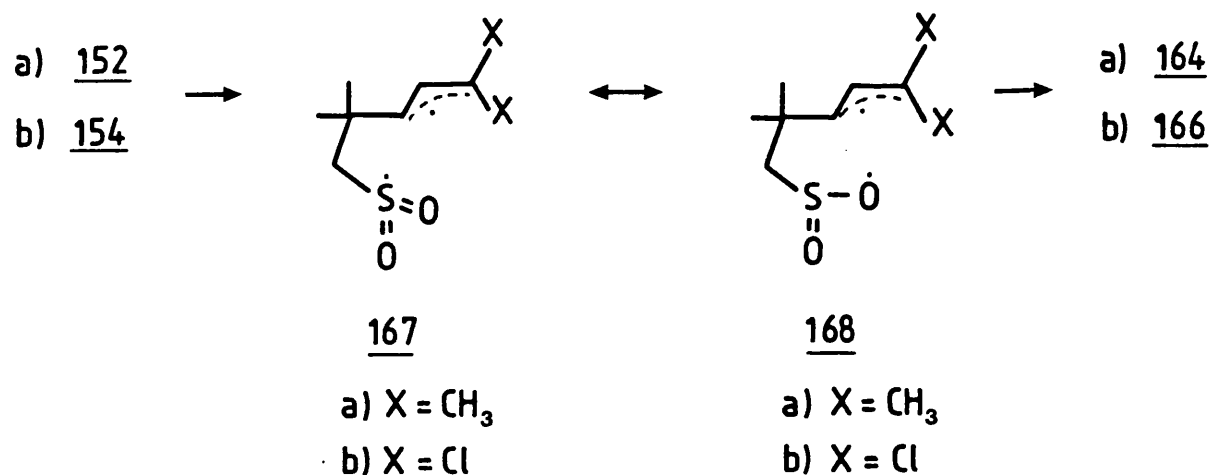
The lower yield of (166) compared to (164) can be explained in terms of the lower stability of the appropriate resonances structure (167b) and (168b) owing to the presence of two chlorine atoms.

In discussing the thermolysis behaviour of (122)[70] (described previously in the introduction to this chapter), King et al argued against homolytic cleavage of the carbon-sulphur bond and against the possibility of diradical intermediate. Instead they proposed an electrocyclic ring opening and a sulphene intermediate, while admitting in doing so that their evidence was mainly circumstantial.
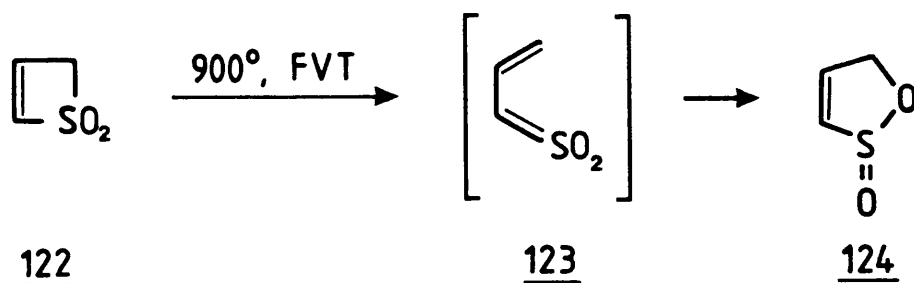
The obvious implication of structures (167) and (168) in the thermolysis of (152) and (155), where no sulphene intermediate is possible and where initial cleavage must be homolytic, casts considerable doubt on these arguments.

The diradical resonance structures (169) and (170) should have similar, if not higher, stabilities to (167) and (168) and thus they can now be proposed as intermediates in the thermolysis of (122).
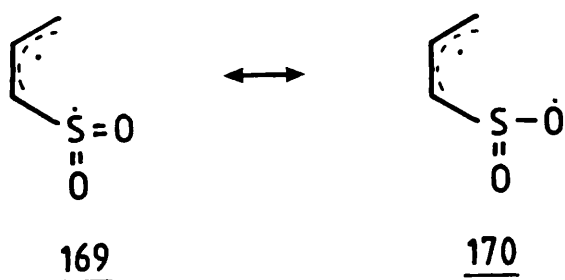
That is not to say that a sulphene intermediate definitely does not participate: the higher yield involved in the thermolysis of (122) compared to those for (152) and (155) provides evidence for the possibility of a different mechanism in the two cases.

The isolation only of products which have retained the sulphur dioxide fragment in the thermolysis of (152) and (155) implies that the reaction conditions are insufficiently vigorous to cause the cleavage of the second sulphur carbon bond before recombination of the radicals. Yet the complete extrusion of sulphur dioxide from a cyclic sulphone can be accomplished under less vigorous conditions; Finlay reported that phenylcyclopropane was the only product in the flash vacuum thermolysis of (89) at 450°C[44] and this result was checked and found to be correct in experimental work undertaken by the present author.

The second sulphur-carbon bond cleaved in the thermolysis of (89) (assuming the benzylic bond to be broken first) appears to be very similar to that which remains unbroken in the thermolysis of (152). Since therefore the temperature is sufficiently high for the cleavage of this second bond, it would seem that the lifetimes of the diradicals (167) and (168) are insufficiently long and that the step (168) to (164)/(166) is far too rapid, even in flash vacuum thermolysis terms, to allow this second cleavage to take place. The author is unable to fully explain why this should be so, although the allylic radical is obviously less delocalised, and therefore more readily available for recombination, than for the benzylic radical produced in the thermolysis of (89).

3.13   Thermolysis of Sulphone (163)

Flash vacuum thermolysis of a sample of crude (163) at 750°C afforded a product mixture containing a number of products, which were analysed

by g.l.c. The two major products were also analysed by g.l.c. mass spectrometry. The g.l.c. analysis of the crude product mixture is given in Table 3.4.

Table 3.4:- Analysis by g.l.c. of the Thermolysis Products of (163) (10% OV17 Column, 162°C, 10 psi Flow Pressure)

Compound	A	B	C	D	E	F
Retention Time (mins;seconds)	1;30	1;45	2;20	4;48	6;42	7;24

Compound (E) corresponded exactly with an authentic sample of trans-methyl chrysanthemate, both by g.l.c. and g.l.c. mass spectrometry (major peaks m/e 182, 167, 151, 139, 123). The yield of this compound (calculated by comparing an average g.l.c. spectrum with that of a trans-methyl chysanthemate solution of known concentration) was poor, approximating to 10% from the crude sulphone.

Compound (D) also had a molecular ion of m/e 182, but its mass spectrum was otherwise significantly different in its peaks and peak intensities (m/e 182, 150, 139, 123). This, combined with its much higher volatility would seem to rule out the possibility of it being the cis-isomer. A possible alternative is the ring-expanded compound (171), which has yet to be reported in the literature.

CO₂Me
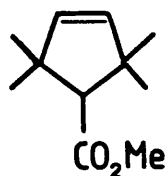
171

Compound (D) and trans-methyl chrysanthemate were the two major products, but with (D) in excess; by g.l.c. assuming very similar calibrations, the ratio (D):(E) was 2:1.

3.14 Mass Spectral Studies

On thermolysis (159) was observed to lose sulphur dioxide to give methyl 2,2-dimethylcyclopropane carboxylate as the dominant product. In the mass spectrometer the corresponding ion m/e 128 gives a surprisingly small peak (Figure 3.4). However, it does appear to be involved in the generation of the base peak ion m/e 97, with a metastable peak at m/e 73 providing good evidence for this. One would presume that loss of a methoxy radical after initial extrusion of sulphur dioxide accounts for this ion, with loss of methanol accounting for its near neighbour m/e 96. Loss of 'SO$_2$' is also involved in the appearance of the second most prominent peak at m/e 113; a metastable peak at m/e 72 (distinct from that at m/e 73) suggests that this ion is derived from ion m/e 178.

So although unaccompanied extrusion of sulphur dioxide is poor, loss of sulphur dioxide is nevertheless the most frequently occurring process observed in the mass spectrometer.

The loss of 'CH$_2$' to give the ion m/e 178 and the loss of the methoxy group to give ion m/e 162 is surprising, especially as no such processes were observed in the case of (104). Another major difference between (159) and (104) is that in the case of (159) no elimination of 'CO$_2$CH$_3$' is observed. This is understandable however,

because in the case of (104) cleavage of the carbonyl carbon-benzyl carbon bond can give either one of two relatively stable species, a benzylic carbonium ion or a benzyl radical. In the case of (159), the absence of a stabilising group such as phenyl added to the destabilising inductive effect of a sulphone group means that any such cleavage is disfavoured.

The tendency of the sulphones described in this chapter not to cleave bonds involved in, or adjoining, the ring is highlighted by the mass spectrum of (147a) (Figure 3.5). The initial fragmentation is loss of the isopropyl group, to give the base peak m/e 163. This process shows complete dominance over extrusion of 'SO$_2$', which is not observed at all. This domination is also apparent in the spectra of (148), (157) and (161). In the case of (100b), loss of the isopropyl group was followed by extrusion of 'SO$_2$'. However this is not observed here; clearly the absence of the carbonium ion or radical stabilising phenyl group means such a process is disfavoured.

One might have expected that the presence of a methoxycarbonyl group in (161) would have led to other processes competing with loss of the isopropyl group. However a peak at m/e 200, corresponding to loss of 'SO$_2$' is not apparent, while loss of 'OMe' and 'CO$_2$Me' to give ions m/e 233 and m/e 205 respectively give peaks that are only a very small percentage of the base peak (Figure 3.6).

The β,γunsaturated sulphones (152) and (155) also give mass spectra worthy of note (Figures 3.7 and 3.8 respectively). Both on thermolysis

gave their isomeric sultines, with no products from extrusion of sulphur dioxide ever isolated. In contrast, peaks in the mass spectra representing molecular weight ions are small. Instead both compounds appear to lose 'SO$_2$' readily (both at 70 eV and 30 eV), with the resultant positive charges presumably stabilised by their allylic positions. In neither case however does the resulting ion give the base peak. For (152) this is reserved for ion m/e 109, formed when loss of 'SO$_2$' is followed by subsequent loss of a methyl group (a metastable peak at m/e 96 confirms this). The question as to which methyl group is lost is more difficult to answer, because the mass spectrum of (155) suggested that loss from two different positions is possible. The ion m/e 129 forms the base peak for (155) and this is formed by loss of 'Cl' after initial extrusion of 'SO$_2$': peaks at m/e 129 and m/e 131 give the familiar pattern for compounds containing only one chlorine and a metastable peak at m/e 101 indicates the order of fragmentation. On the other hand the mass spectrum (155) also contains the peaks m/e 149, 151 and 153 (in the proportions 9:6:1), representing loss of a methyl group from the quarternary carbon. Thus (155) shows that a group can be lost from this position or from a vinylic position, and hence the exact composition of the ion m/e 109 observed for (152) is unclear.

Possibly the most interesting aspect of the spectra of (152) and (155) is the observed loss of 56, representing the loss of an isobutene group. This probably occurs via a retro (2+2) addition (Scheme 41) and means that, apparently, the ion observed is a conjugated sulphene.

The peaks are very small but prompt the question: could a similar

process take place on thermolysis?
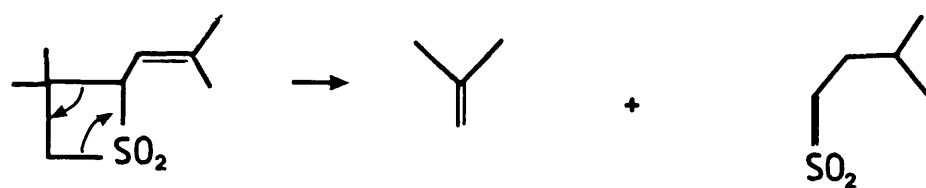
152

Scheme 41
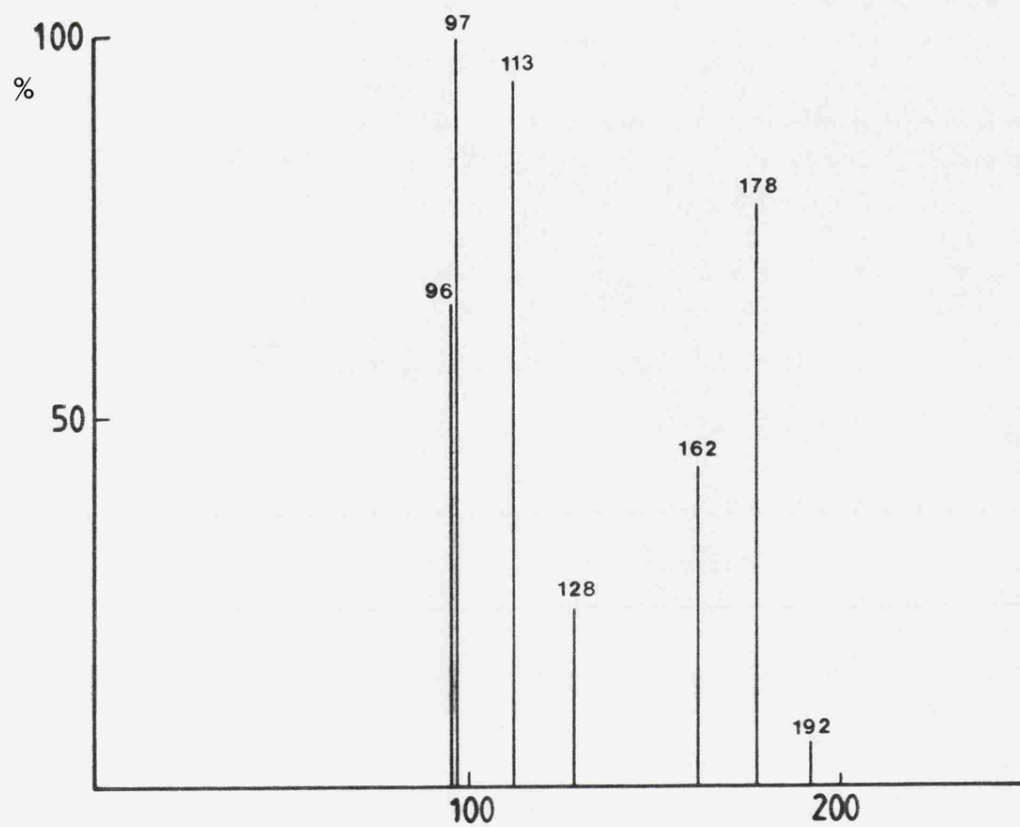
FIGURE 3.4

Mass spectrum of (159) at 70 eV.
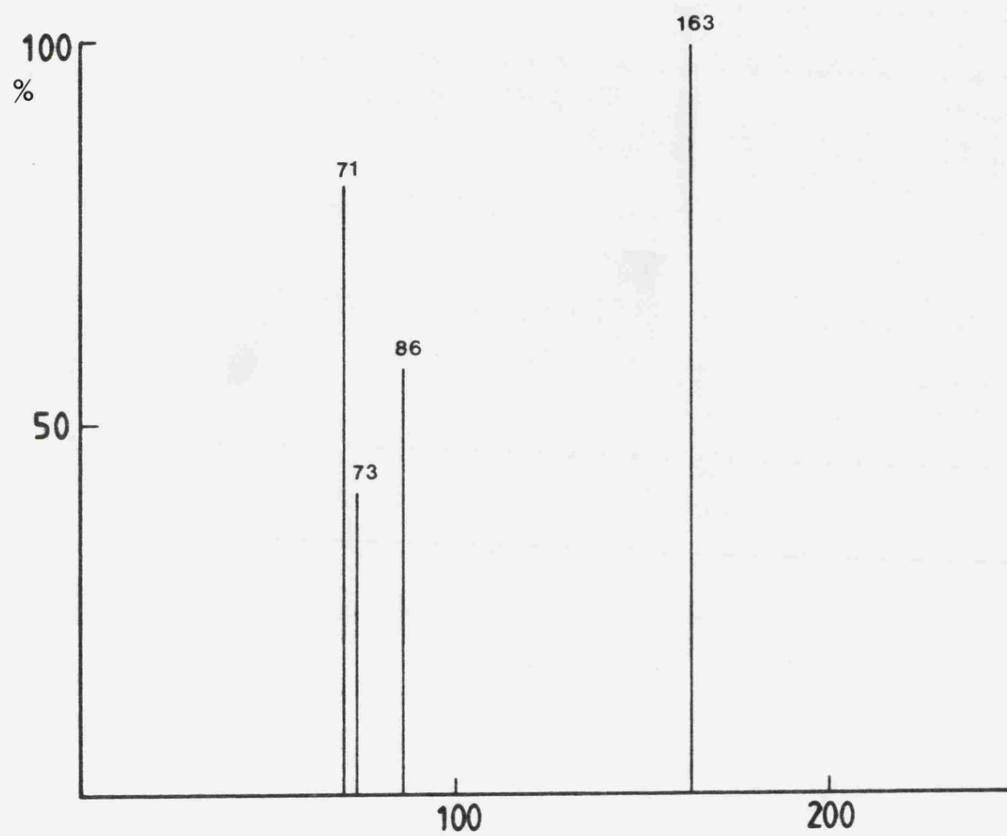
FIGURE 3.5

Mass spectrum of (147a) at 75 eV.

FIGURE 3.6
Mass spectrum of (161).

FIGURE 3.6
Mass spectrum of (161).
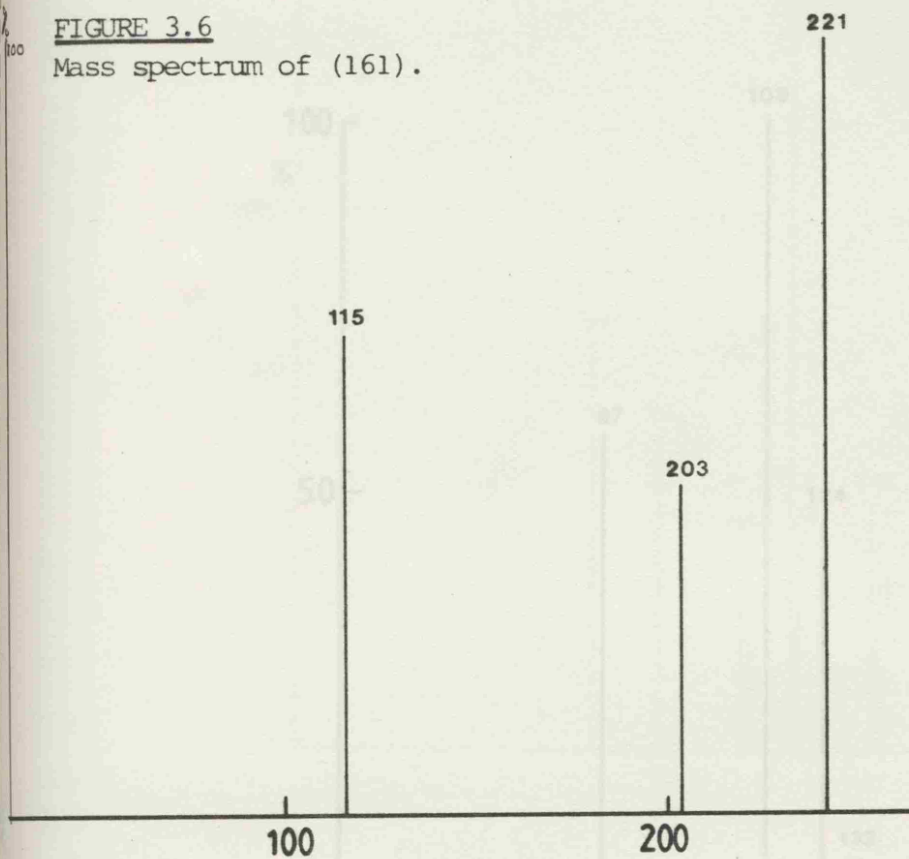
FIGURE 3.7
Mass spectrum of (152) at 70 eV.
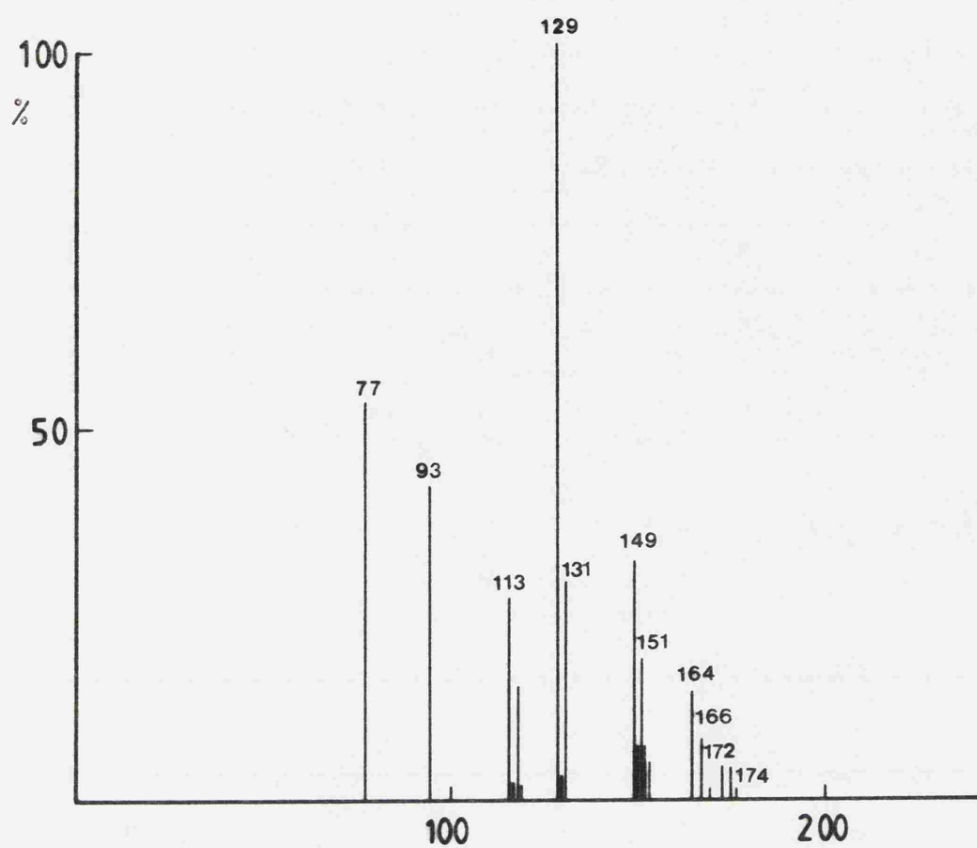
FIGURE 3.8

Mass spectrum of (155) at 70 eV.

CHAPTER FOUR

SOME PHASE TRANSFER PREPARATIONS OF CYCLIC SULPHIDES

4.1 Introduction

This chapter investigates the preparation of some cyclic sulphides using the principle of phase transfer catalysis, all the sulphides in question having been previously prepared by some other method. The most common method previously employed has been to treat the appropriate halogeno compound with sodium or potassium sulphide in water or an alcohol-water mixture at about 70°C. Fidler et al reported very good yields, often 90%, for crude sulphides using this method[55,103]. Generally the group used primary halides but found that for isopropyl bromide the reaction was considerably slower (Scheme 42).

$$CH_3I \xrightarrow{Na_2S} CH_3SCH_3$$

$$CH_3CH_2CH_2Br \xrightarrow{Na_2S} CH_3CH_2CH_2SCH_2CH_2CH_3$$

$$(CH_3)_2CHBr \xrightarrow{Na_2S} (CH_3)_2CHSCH(CH_3)_2$$

$$BrCH_2CH_2CH_2CH_2Br \xrightarrow{Na_2S} \overline{CH_2CH_2CH_2CH_2S}$$
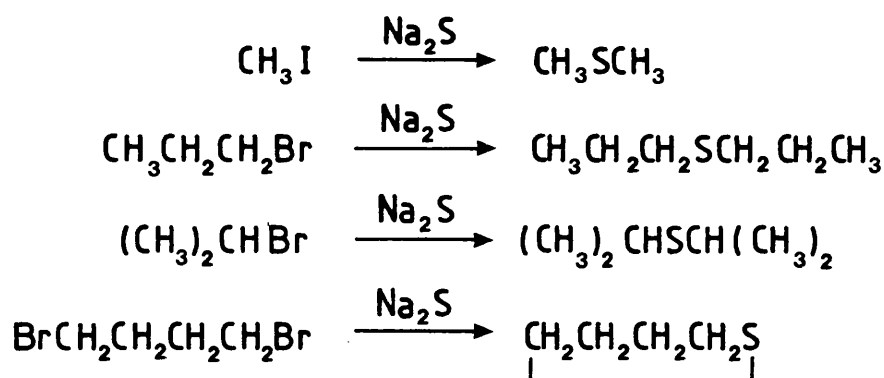
Scheme 42

Exemplifying benzylic bromides, 2,3-bis(bromomethyl)naphthalene (172) heated under reflux with excess sodium sulphide in a mixture of water and IMS gave 1,3-dihydronaphtho[2,3-c]thiophene (173) in good yield (65%)[7]. The yield of 1,3-dihydronaphtho[1,2-c]thiophene (175) from 1,2-bis(bromomethyl)naphthalene (174) was reported as being slightly lower (58%).

172   173

174   175
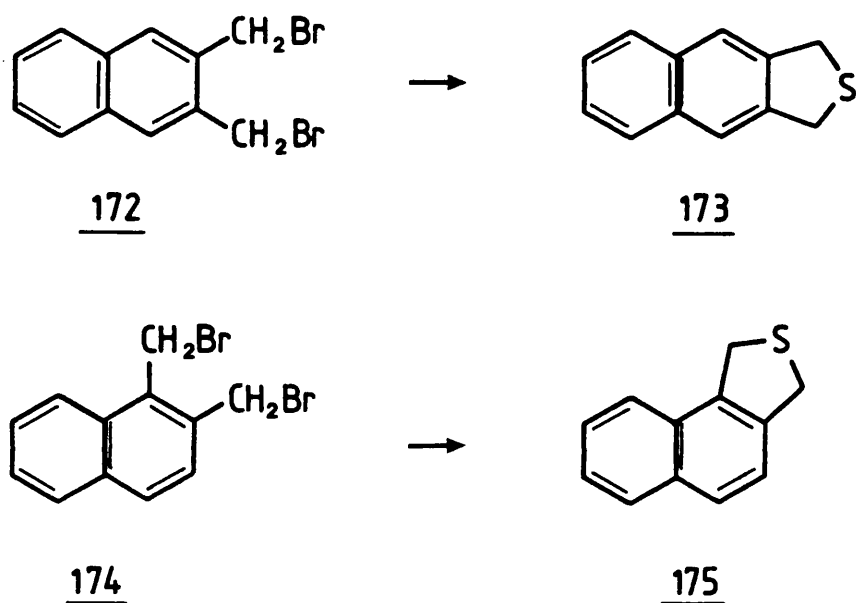
The preparation of strained ring structures tends to lead to lower yields; thietans for example are generally prepared in 30-55% when this method is employed[104].

Yields for this general method are limited owing to the formation of polymeric thioethers. Bost et al reported that polymerisation was greater with a 20% excess of sodium sulphide instead of a stoichiometric quantity[105].

A slight variation on the method was made by Newman et al[89] in the preparation of a cyclic sulphide when using a dimesylate (145) instead of a dihalo compound and ethanediol as solvent instead of a monohydric alcohol-water mixture. The ditosylate (146) was found to be equally effective in the course of the work described in Chapter 3. Also described in Chapter 3 was the treatment of a cyclic carbonate (143) with potassium thiocyanate to give the appropriate cyclic sulphide (144).

Alkaline aqueous solutions of mercaptans mixed with alkyl halides have also been used previously, particularly if the sulphide in question is unsymmetrical[103].

Other less commonly employed methods of sulphide preparation are exemplified by the syntheses described in Scheme 43, namely treatment of a hydroxyalkyl halide with thiourea followed by aqueous potassium carbonate[106] and alkaline hydrolysis of a chloromethyl thiirane[107].

$$HO\diagdown\diagup\diagdown\diagup Cl \xrightarrow{(NH_2)_2CS} \left[HO\diagdown\diagup\diagdown\diagup S\diagdown_{C(NH_2)_2} \right]^+ Cl^- \xrightarrow{{}^-OH} \square_S$$

$$\triangle_S\diagdown\diagup Cl \xrightarrow{{}^-OH} HO{-}\overset{Cl}{\underset{S^-}{\diagup}} \longrightarrow \overset{OH}{\square_S}$$
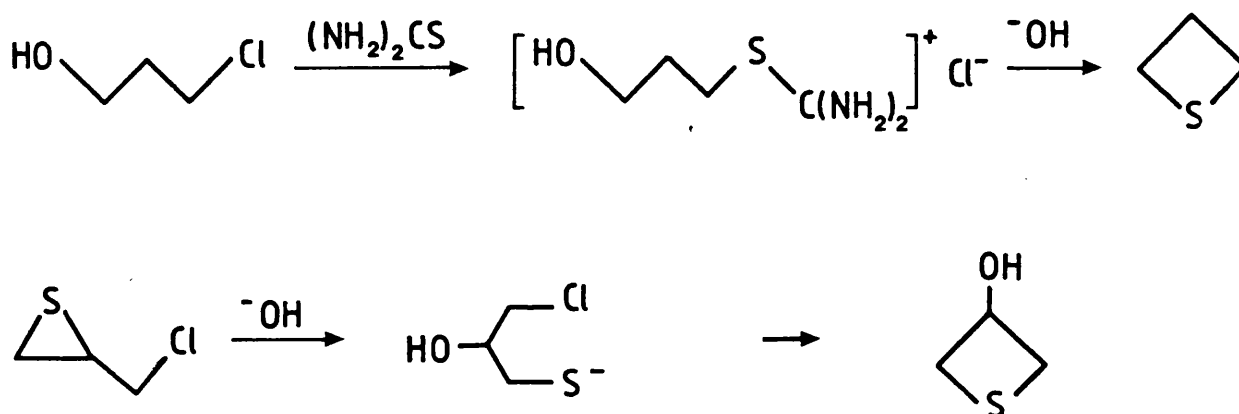
Scheme 43

A primary difficulty in the reaction of a salt and an organic substrate tends to be solubility, the salts being less soluble in the solvent used than in water and the organic substrate less soluble than in hydrocarbons. Dipolar aprotic solvents such as dimethylformamide (DMF), DMSO and HMPT have been utilised and these often help overcome such solubility problems. They are essentially cation solvators and this often has the beneficial side effect of leaving the anion relatively unsolvated and therefore more reactive. However such solvents may be expensive, hard to purify, and difficult to keep anhydrous.

A non-polar solvent with a cation solvating additive may also be effective, for example beta diamines help solvate organolithium compounds[108].

Phase transfer catalysis is a fairly recent development. Jarousse first recognised the principle[109] and the term 'ion pair extraction' was later coined by Brandstrom[110]. The latter went on to introduce the term 'phase transfer catalysis' which is the expression now in general use.

The process generally allows a large number of alternatives for the choice of solvent to dissolve the organic substrate (the main restriction being that for a liquid-liquid system it must be immiscible with water).

The salt can be present in the solid phase or dissolved in water. A choice of phase transfer catalysts exists: quaternary ammonium or phosphonium salts, crown ethers, cryptands or tertiary amines. For a liquid-liquid system, quaternary salts are generally used, while for a solid-liquid phase transfer system an uncharged catalyst generally must be used.

The phase transfer catalyst complexes with the salt or anion either in aqueous phase or at the phase interface. The new complex then becomes resolvated in the organic phase. So for a quarternary salt (represented by Q+X-) the process can be summarised in Scheme 44.

$$Q^+X^-(org) \rightleftharpoons Q^+X^-(aq) + M^+A^- \rightleftharpoons Q^+A^-(aq) + M^+X^-(aq)$$

$$\Updownarrow$$

Scheme 44 $\qquad\qquad Q^+A^- (org)$
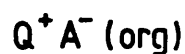
The anion A^- is thus made available for reaction with the organic substrate in the organic phase. Conditions for a successful reaction tend to be less vigorous than when a hydrophilic/lipophilic solvent is used.

The best quaternary salts for phase transfer catalysis have been proven by experiment to be those containing bulkier alkyl groups[111,112]. This is believed to be because the positive charge is more hidden and the anion consequently more reactive. For crown ethers it is high lipophilicity, leading to high solubility in the organic medium, that is regarded as being the most important factor in producing an efficient catalyst[112].

Phase transfer catalysis has been extended to incorporate the synthesis of sulphides. Landini et al have successfully prepared dialkyl and aryl alkyl sulphides by this method[113,114]; a two phase system of alkyl halide, aqueous sodium sulphide (0.6 equivalent) and hexadecyltributylphosphonium bromide was heated to 70° to give high yields of the symmetrical dialkyl sulphides[113]. No organic co-solvent was used. Secondary alkyl halides also give the appropriate sulphides in high yield, although a longer reaction time is required[113]. Alkyl aryl sulphides were prepared under similar conditions using an appropriate sodium mercaptide instead of sodium sulphide[112,115].

Using the appropriate aryl chloride, bis(nitrophenyl)sulphides have

also been prepared using this general method, although in only mediocre

yield[116].

The strained thietan ring can also be synthesised by this technique.

Lancaster used 1,3-dibromides and mild conditions to prepare thietan

and some substituted thietans in yields much improved over those of

previously used methods[41]. A secondary dibromide again reacted much

more slowly than a primary bromide, (this time by one order of

magnitude), but again represented a considerable improvement over

previous methods.

However, many 1,3-dibromides are not readily available and they

include at the time of writing 1,3-dibromo-2,2-dimethylpropane (176),

the bromide used for the preparation of 3,3-dimethylthietan (144),

which has been shown to be synthetically useful in Chapter 3.

$$\underset{\textbf{Br} \qquad \textbf{Br}}{\text{(structure)}} \longrightarrow \underline{\textbf{144}}$$

$$\underline{\textbf{176}}$$
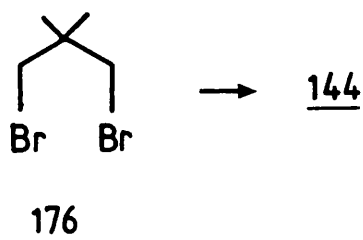
Attempts were to be made therefore, to achieve this cyclisation

using the more readily available disulphonates (145) and (146).

The use of phase-transfer catalysis to prepare dialkyl or cyclic

sulphides from disulphonate esters has not been previously reported,

although it has been shown that a sulphonate group can be displaced

by a range of nucleophiles using this method[114]. This was achieved

using crown ethers and fairly vigorous conditions. No organic solvent was employed and the reaction temperature was always 100°C, higher than that used for the same reaction of the corresponding alkyl halide.

In the ensuing description of some new reactions involving phase transfer catalysis, various catalysts were used, namely benzyltriethyl-ammonium chloride (BTEAC), cetyltriethylammonium chloride (CTEAC), tetra-n-butylammonium bromide (TBAB) and dicyclohexyl-18-crown-6. It has been recognised that some catalysts are more efficient than others, such efficiencies being dependent on conditions used, size and shape of the alkyl groups attached to the cation etc[112]. However, no studies involving comparison of the various catalysts were made here. For each of the reactions described a reasonably suitable catalyst was used. For the preparation of (144) from disulphonate esters (145) and (146) both a quaternary ammonium salt and a crown ether were tried. It is not believed that the choice of catalyst was the mitigating factor for any of the reactions which ultimately failed.

4.2   Preparation of 1,3-Dihydronaphthothiophenes

Stirring a solution of (172) in dichloromethane with an aqueous sodium sulphide solution in the presence of TBAB at room temperature gave the cyclic sulphide (173) quantitatively. This represents a considerable improvement in yield over the previous method of conversion, when a boiling water-ethanol reaction mixture was used[7].

172   173
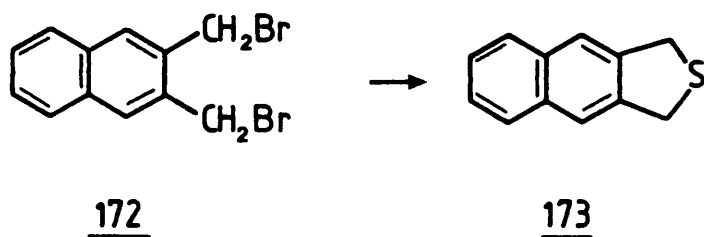
The preparation of (175) from (174) under similar phase transfer

catalysed conditions, was not so straightforward. The initial product

was a solid which had low solubility in organic solvents, gave broad

indistinct peaks in its ^{1}H n.m.r. spectrum and had a high melting

point and was therefore concluded to be a polymer. Heating this

solid under vacuum in a sublimation apparatus resulted in the

condensation of (175) onto the cold finger. Thus the polymer is of

such a structure as to allow thermal rearrangement into the monomer

sulphide.

It would seem safe to assume that initial substitution of the

sulphide dianion is taking place at one of the arylmethyl positions

in the same way as it did for the formation of (173). However to

subsequently form a polymer means that there must then occur an

intermolecular reaction, in preference to an intramolecular one.

This implies that the reactivity of one of the arylmethyl positions

is considerably higher than at the other.

174   175
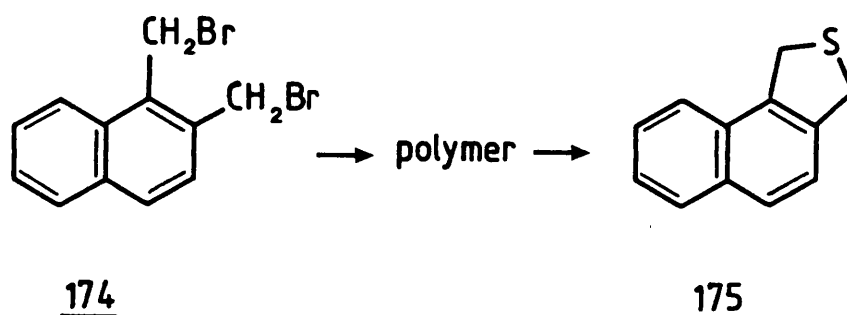
Kinetic studies of S_n2 reactions involving 1-halomethylnaphthalenes (177) and their 2-isomers (178) are very sparse. Considerably more, though by no means comprehensive, work has been done on their S_n1 reactions. SCF-MO calculations clearly show that a (177) type compound should be more reactive than its 2-isomer: considering the pure or limiting S_n1 case the energy difference between the arylmethyl cation and its parent is between 68 and 329 eV (depending on the exact method used) more favourable to the 1-isomer[117].
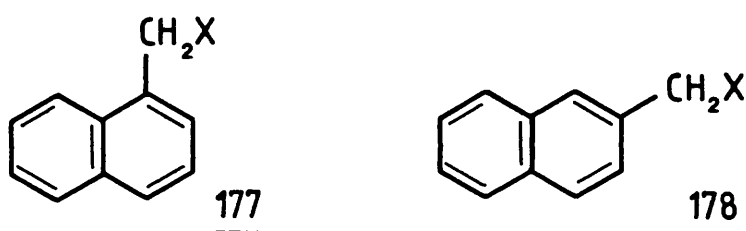
Early experimental work showed that the rate of solvolysis of 2-(chloromethyl)naphthalene (178, X = Cl)) corresponded to that theoretically predicted but that the solvolysis of (177, X = Cl) appeared to be slower than expected, although it was still the more reactive of the two[118]. Dewar and Sampson initially attributed this to steric hindrance in ions of the 1-methylnaphthalene type resulting from peri interactions, but Dewar himself later stated that the deviation from theory was the result of crude experimental technique[119]. Indeed Gleicher's calculations would appear to show that the introduction of an allowance for strain effects in this case actually impairs the correlation between the calculated energy of ionisation and experimental result[120]. Nevertheless, peri-interactions are still blamed when the reaction rate of a (177) type compound is slower than expected[121].

The calculations and kinetic studies mentioned so far have involved mechanisms approximating to S_n1. In the case of displacement of bromine by a sulphide anion from (172) or (174) we are considering a mechanism much closer to S_n2. Studies in this area specifically relating to (177) and (178) are virtually non-existent. In the case of (177) Dewar and Sampson stated that a greater involvement of the nucleophile leads to a less planar and consequently less strained transition state[118(b)]. For example, solvolysis in moist formic acid would lead to a strain energy for the transition state which is 33 kcal mol^{-1} greater than for displacement by Iodide in anhydrous acetone. However, as already mentioned, Dewar and Bentley[119], along with Gleicher[120], later disputed the findings of this publication.

While the picture remains rather confused, what is clear is that (177) can be solvolysed up to 15 times quicker than its 2-isomer (178) in a number of polar solvents. Extrapolating this into S_n2 reactions may not be straightforward, but it would seem reasonable to suggest that polymerisation in the reaction of (174) with sodium sulphide is caused by substitution at the 1-position occurring in preference to substitution at the 2-position, even when the former is intermolecular and the later intramolecular.

Conducting the reaction at higher temperature (refluxing chloroform) led to the detection of (175) in the crude product (although the polymer was still present and the isolated yield of (175) was still considerably less than that obtained from a refluxing water-ethanol

reaction mixture[9]). This suggests that either there was a considerable energy barrier to the intramolecular step or that the activation energy difference between the intramolecular and intermolecular steps has been reduced. However it would be dangerous to draw any further conclusions than that from this one result.

4.3   Preparation of Thiacyclohexan-4-one

Preparation of thiacyclohexan-4-one (180) was achieved in good yield under phase transfer conditions from the dichloride (179), although the yield was probably reduced by loss of the water soluble (180) into the aqueous phase during work up. The conditions required were milder than those normally needed for primary chlorides, probably because of activation of the 1,5-positions by the β-keto group.
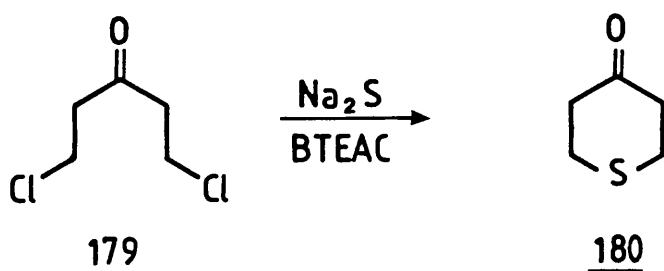
4.4   Preparation of 3,3-Dimethylthietan

Although 3,3-dimethylthietan (144) has previously been prepared from the 1,3-dibromide (176) under mild conditions using phase transfer catalysis, attempts to prepare (144) from the 1,3-disulphonate esters (145/146) under similar conditions were unsuccessful. Both the dimesylate and ditosylate failed to give any of the desired product, even when the reaction temperature was raised from room temperature (used for the dibromide) to 61°C. Although the dimesylate may have

been preferable as a substrate to the ditosylate for reasons such as greater water solubility of the leaving group, it tended to decompose at this temperature, and all experiments involving higher temperatures were conducted using the ditosylate.

Benzene was then used as the organic co-solvent and the temperature of the liquid-liquid reaction mixture was raised to 80°C, but again (144) was not detectable. However, when this temperature was employed for a solid-liquid system, with the sodium sulphide having been previously azeotroped dry, (144) was both detected and isolated. This suggests that, even when in an organic medium, the sulphide dianion is still shielded by water molecules when water is present in the reaction mixture.

$$OSO_2R \quad OSO_2R \longrightarrow \underline{144}$$

$$\underline{145} \quad R = CH_3$$
$$\underline{146} \quad R = \underline{p} - CH_3C_6H_4$$
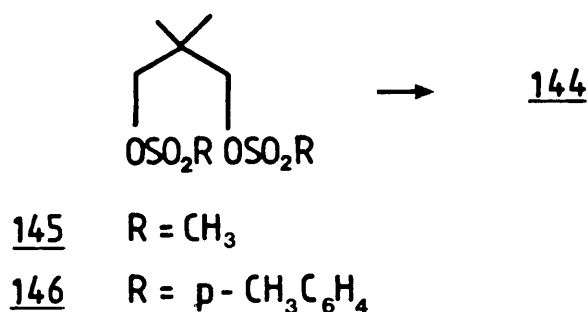
Unfortunately the solid-liquid phase transfer system proved unsuitable for the preparation of (144) in any sizeable quantities, owing to the close proximity of the boiling points of the product and the solvent. However this method may prove suitable for the preparation of less volatile sulphides.

EXPERIMENTAL

Instrumentation

Infrared spectra were recorded on a Perkin-Elmer 237. Mass spectra were determined using a V.G. Micromass 16B instrument, with a gas chromatograph attachment. The molecular ion, if seen, is given first, followed by peaks of structural significance.

^{1}H n.m.r. spectra were recorded on either a Varian T60, an EM390 or a Brucker 400 instrument, using deuteriochloroform as solvent and tetramethylsilane as internal standard, unless otherwise stated. ^{13}C n.m.r. were recorded on a Brucker 400 instrument.

Melting points were determined on a Kofler heating stage and are uncorrected. Gas-liquid chromatography was carried out on a Pye-Unicam series 104 chromatograph. Preparative gas-liquid chromatography was carried out on a Pye-Unicam series 105 chromatograph, using a 10% OV17 column.

General

Solutions in organic solvents were dried over magnesium sulphate, unless otherwise stated. A rotary evaporator was used for the removal of solvents at reduced pressure, unless the volatility of the products was considered too great.

Petroleum ether was of boiling range 60-80°C unless otherwise stated. Super-dry diethyl ether and THF were obtained by storing over

sodium wire and then distilling from lithium aluminium hydride immediately prior to use. Methanol was refluxed over and distilled from calcium hydride. All solvents used for recrystallising were distilled prior to use.

Photolyses were carried out using a Rayonet Photochemical Reactor, fitted with lamps emitting light of the required wavelength. The solutions were contained in a quartz tube and all solvents were deoxygenated immediately prior to use.

Column chromatography was carried out using one of four types of packing:- alumina (UG1), silica M.F.C., t.l.c. grade silica or silica suitable for flash chromatography.

CHAPTER ONE

Preparation of 2,3-bis(bromomethyl)naphthalene (172)

2,3-Bis(bromomethyl)naphthalene was prepared in 59% yield by the reaction of 2,3-dimethylnaphthalene with N-bromosuccimide in boiling carbon tetrachloride in the presence of benzoyl peroxide, as described by Bodem and Ried[122]. Recrystallisation was omitted, m.p. 158-160°C (lit. [122] m.p. 164-165°C).

1,3-Dihydronaphtho[2,3-c]thiophene (173)

For the preparation of this compound, see Chapter 4.

1,3-Dihydronaphtho[2,3-c]thiophene 2,2-dioxide (17)

The sulphone (17) was prepared in 55% yield from the sulphide (173) using peracetic acid, as described by Cava and Shirley[7], m.p. 250-252°C (lit.[7] m.p. 251-255°C).

1,2-Bis(bromomethyl)naphthalene (174)

The dibromide (174) was prepared in 77% yield from 1,2-dimethylnaphthalene using N-bromosuccinide and benzoyl peroxide in boiling carbon tetrachloride, as described by Bodem and Ried[122], m.p. 151-152°C (lit.[122] m.p. 153°C).

1,3-Dihydronaphtho[1,2-c]thiophene (175)

The sulphide 9175) was prepared in 64% yield from 1,2-bis(bromomethyl)naphthalene using sodium sulphide in a boiling water-

ethanol solution, as described by Cava et al[9], m.p. 72-78°C (lit.[9] m.p. 70-78°C).

1,3-Dihydronaphtho[1,2-c]thiophene 2,2-dioxide (21)

To a stirred solution of 1,3-dihydronaphtho-[1,2-c]thiophene (4.9g, 26.3 mmole) in dichloromethane (30 ml) at 0°C was added a solution of 85% m-chloroperbenzoic acid (11.7g, 57.7 mmole) in dichloromethane (100 ml) over 0.5 hours. The ice bath was removed and the reaction mixture stirred overnight. The mixture was diluted with dichloromethane (50 mls) and filtered, washing well the collected precipitate. The filtrate was eluted through alumina (80g) using dichloromethane as elutant. The solution was collected as one fraction, from which the solvent was evaporated. Recrystallisation from chloroform gave 1,3-dihydronaphtho[1,2-c]thiophene 2,2-dioxide (2.4g, 60%) m.p. 163-164°C and 169-171°C (lit.[9] m.p. 165-166°C and 170.5-171°C) δ(CDCl$_3$) 8.13-7.22 (6H,m); 4.67 (2H,s); 4.53 (2H,s).

1,3-Dihydro-1-methylnaphtho[2,3-c]thiophene 2,2-dioxide (57a)

To a stirred solution of 1,3-dihydronaphtho[2,3-c]thiophene 2,2-dioxide (0.75g, 3.44 mmole) in dry THF (120 ml) at -78°C under an atmosphere of dry nitrogen, n-butyl-lithium (1.1 equivalent) was added dropwise over 10 minutes and the reaction mixture was stirred for a further 40 minutes to give a brown solution. Methyl iodide (2 ml, 32 mmole) was added and the reaction mixture warmed gradually, with stirring, to room temperature and stirred overnight. The reaction was quenched with saturated brine solution (10 ml) and stirred for 2 minutes. The organic layer was separated and the solvent removed. The

residue was redissolved in dichloromethane (100 ml), washed with

water (2 x 50 ml) and dried. Removal of the solvent and recrystallisation

gave 1,3-dihydro-1-methylnaphtho [2,3-c]thiophene 2,2-dioxide (0.47g,

59%) m.p. (chloroform-petrol) 198.5-200°C, ν_{max} (CH_2Cl_2) 1315, 1125

and 1115 cm^{-1}, δ($CDCl_3$) 7.9-7.3 (6H,m); 4.53-4.23 (3H,m); 1.75 (3H,d,J =

8 Hz) m/e 232, 168, 138, 123. $C_{13}H_{12}O_2S$ requires C, 67.22; H,

5.21, Found: C, 67.41; H, 5.26.

1,3-Dihydro-1-(Pent-4-enyl)naphtho[2,3-c]thiophene 2,2-dioxide (57b)

n-Butyl-lithium (1.1 equivalent) was added over a period of 10

minutes to a stirred solution of 1,3-dihydronaphtho[2,3-c]thiophene

2,2-dioxide (0.58g, 2.66 mmole) in dry THF (140 ml) at -78°C under an

atmosphere of dry nitrogen. The mixture was stirred at -78°C for 10

minutes then warmed gradually to room temperature over a period of 30

minutes to give a brown solution. After recooling to -78°C, excess 5-

bromopent-1-ene (0.8g, 5.37 mmole) was added and the reaction mixture

was then allowed to warm to room temperature and stirred for a further

24 hours. Brine (60 ml) was added, the reaction mixture stirred for

a few minutes and the organic layer separated and evaporated. The

residue was redissolved in dichloromethane (200 ml), washed with

water (2 x 50 ml) and dried. Removal of the solvent and chromatography

on alumina (18g), eluting with dichloromethane, gave (57b) (0.45g,

59%), m.p. (chloroform-petrol) 110-111°C, ν_{max} (CH_2Cl_2) 1310 and

1125 cm^{-1}, δ($CDCl_3$) 7.93-7.36 (6H,m); 6.10-5.50 (1H,m); 5.20-4.91

(2H,m); 4.50-4.20 (3H,m); 2.42-1.60 (6H,m), m/e 286, 222, 181, 179,

165, $C_{17}H_{18}O_2S$ requires C, 71.30; H, 6.33, Found: C, 71.29; H, 6.27.

1,5-Dichloropentan-3-one (179)

1,5-Dichloropentan-3-one was prepared in 70% yield from the reaction of 3-chloropropionyl chloride with aluminium chloride and ethylene in dichloromethane, using the method described by Baddeley et al,[123] b.p. 60-62°C at 0.15 mm/Hg, (lit.[123] b.p. 78°C at 0.8 mm/Hg).

Divinyl Ketone

Quantities of this compound were obtained by distilling 1,5-dichloropentan-3-one from excess anhydrous sodium carbonate under reduced pressure and redistilling, b.p. 40°C at 25 mm/Hg (lit.[124] b.p. 30°C at 16 mm/Hg). The yield was not optimised (lit.[124] 90%).

β-Chloroethyl Vinyl Ketone

β-Chloroethyl vinyl ketone was obtained by distillation from a 1.0 equivalent of anhydrous sodium carbonate, as described by Danishefsky and Migadalof[22], and redistilled b.p. 26-32°C at 0.1 mm/Hg. The yield was not optimised (no lit. yield given[22]).

Attempted Reaction of the 1,3-Dihydronaphtho[2,3-c]thiophene 2,2-dioxide (17) Anion with Divinyl Ketone

Using the method described for the preparation of (57b), the anion of the sulphone (17) (0.5g, 2.3 mmole) was generated in THF at -78°C and divinyl ketone (0.28 ml, 2.86 mmole) was added. The mixture was allowed to warm to room temperature and stirred for a further 2 hours, by which time the solution still had a brown colouration but had also become cloudy. Work up as before gave the starting sulphone (0.25g) and a white solid that was polymeric in behaviour.

Attempted Reaction of the 1,3-Dihydronaphtho[2,3-c]thiophene 2,2-dioxide (17) Anion with β-Chloroethyl Vinyl Ketone

Using the method described above, the anion of the sulphone (17)

(1g, 4.6 mmole) was generated in THF at -78°C using n-butyl-lithium,

and β-chloroethyl vinyl ketone (0.75g, 6.4 mmole) was added. The

reaction mixture was allowed to warm to room temperature and stirred

for a further 2.5 hours, after which time the reaction mixture was

yellow and cloudy. Work up as before gave the starting sulphone

(0.65g) and a white solid that was polymeric in behaviour. None of

the electrophile was recovered.

2,2-Bis(2-chloroethyl)-1,3-dioxolane (58)

A solution of 1,5-dichloropentan-3-one (4g, 25.8 mmole) and p-

toluenesulphonic acid (0.3g, 1.74 mmole) in benzene (100 ml) was

mixed with ethanediol (25 ml) in a flask fitted with a Dean-Stark

apparatus and condenser. The mixture was heated under reflux with

vigorous sitrring for 1.5 hours and then allowed to cool before

pouring into water (200 ml). The organic layer was separated, the

aqueous layer further extracted with ether (50 ml) and the organic

layers combined, washed with water (50 ml) and dried. Removal of the

solvent and other volatile compounds under vacuum, followed by

sublimation gave 2,2-bis(2-chloroethyl)1,3-dioxolane (3.9g, 76%),

b.p. 72°C at 0.2 mm/Hg, m.p. (petrol) 32-33°C, ν_{max} (neat) 2950, 2880,

1355, 1190, 1170, 1120, 1100, 1030, 890 and 730 cm^{-1}, δ(CDCl$_3$) 3.90

(4H,s); 3.53 (4H,t,J=7.5 Hz); 2.11 (4H,t,J=7.5 Hz), m/e 135, 91, 63,

$C_7CH_{12}Cl_2O_2$ requires C, 42.23; H, 6.08, Found: C, 42.16; H, 6.04.

1,5-Diiodopentan-3-one

To a solution of 1,5-dichloropentan-3-one (5g, 32.3 mmole) in dry acetone (50 ml) was added sodium iodide (20g, 133 mmole) and the suspension was heated under reflux for 1 hour. On cooling the solvent was removed under vacuum and the residue taken up in a mixture of water (50 ml) and ether (50 ml). The organic layer was separated, washed with water (50 ml) and dried. Removal of the solvent and recrystallisation gave 1,5-diiodopentan-3-one (7.8g, 71.5%), m.p. (ether-petrol) 48-48.5°C, ν_{max} (CH$_2$Cl$_2$) 1720, 1408, 1360, 1230, 1172 and 1075 cm^{-1}, δ(CDCl$_3$) 3.46-2.97 (8H,m), m/e 338, 210, 182, 155, C$_5$H$_8$I$_2$O requires C, 17.77; H, 2.39, I, 75.11, Found: C, 17.49; H, 2.28; I, 74.72.

2,2-Bis(2-iodoethyl)-1,3-dioxolane (59)

A solution of 1,5-diiodopentan-3-one (4.5g, 13.5 mmole) and p-toluenesulphonic acid (0.5g, 2.9 mmole) in benzene (100 ml) was mixed with ethanediol (25 ml) in a flask fitted with a Dean-Stark apparatus and a condenser. The mixture was heated under reflux with vigorous stirring for 2.5 hours, then allowed to cool and poured into water (150 ml). The organic layer was separated, the aqueous layer further extracted with ether (200 ml) and the organic layers combined, washed with water (50 ml), dried and evaporated. The residue was dissolved in hot petrol and the solution decanted from the insoluble dark oil that remained. Recrystallisation gave 2,2-bis(2-iodoethyl)-1,3-dioxolane (3.15g, 61%), m.p. (petrol) 53-53.5°C, ν_{max} (CH$_2$Cl$_2$) 2950, 2890, 1332, 1208, 1172, 1110, 1070, 1034, 940 and 855 cm^{-1}, δ(CDCl$_3$) 3.97 (4H,s); 3.11 (4H,t,J=8.5 Hz); 2.23 (4H,t,J=8.5 Hz), m/e 254, 228,

155, 110, $C_7H_{12}I_2O_2$ requires C, 22.01; H, 3.17; I, 66.45, Found: C, 21.95; H, 3.12; I, 66.21.

Attempted Reaction of the 1,3-Dihydronaphtho [2,3-c]thiophene 2,2-dioxide (17) Anion with 2,2-bis-(2-chloroethyl)1,3-dioxolane (58)

To a stirred solution of the sulphone (17) (0.3g, 1.37 mmole) in dry THF (100 ml) at -78°C under an atmosphere of dry nitrogen was added n-butyl-lithium (1 equivalent) over a period of 10 minutes. The reaction mixture was stirred at -78°C for a further 40 minutes to give a light brown solution. The dichloride (58) (0.4g, 2 mmole) was added and the reaction mixture allowed to warm gradually to room temperature. It was stirred overnight. On work up, the only identifiable compounds were starting materials. In a separate experiment, the inclusion of a few drops of HMPT in the reaction mixture gave the same result.

Attempted Reaction of the 1,3-Dihydronaphtho[2,3-c]thiophene 2,2-dioxide (17) Anion with 2,2-bis(2-iodoethyl)1,3-dioxolane (59)

This reaction was attempted several times using the general method described above. The anion of the sulphone (17) was generated in THF at -78°C using n-butyl-lithium and the diiodide (59) introduced, either in a THF, or benzene, solution or as a solid. The reaction mixture was allowed to warm to room temperature but usually within 15 minutes of the electrophile being introduced it had assumed a reddish brown colour instead of the brown colour of the sulphone anion. However on each occasion work up gave starting materials as the only identifiable compounds.

When the reaction was quenched with deuterium oxide 15 minutes

after the introduction of the diiodide, work up and chromatography on

silica M.F.C., eluting with dichloromethane, gave 2,2-bis(2-iodoethyl)

1,3-dioxolane and a mixture of 1,3-dihydronaphtho[2,3-c]thiophene 2,2-

dioxide and its mono- and dideuteriated derivatives m/e 220/219/218,

153/154/155/156.

Deuteriation of the 1,3-Dihydronaphtho[1,2-c]thiophene 2,2-Dioxide (21)

To a stirred solution of the sulphone (21) (0.19g, 0.87 mmole) in

dry THF (60 ml) at -78°C under an atmosphere of dry nitrogen was

added n-butyl-lithium (1.1 equivalent) over a period of 10 minutes.

The reaction mixture was allowed to warm to room temperature, then

recooled to -78°C and stirred for a further 20 minutes to give a dark

green solution. Deuterium oxide (1 ml) was added. Work up and

chromatography on alumina (2g) gave a mixture of deuteriated sulphones

(0.1g), δ(CDCl$_3$) 7.97-7.24 (6H,m); 4.67 (1.33H,2); 4.53 (1.15H,s).

1-Benzyl-1,3-Dihydronaphtho [1,2-c]thiophene 2,2-dioxide (66b) and its 3-Benzyl Isomer (67b)

To a stirred solution of 1,3-dihydronaphtho [1,2-c]thiophene 2,2-

dioxide (0.75g, 3.44 mmole) in dry THF (120 ml) at -78°C under an

atmosphere of dry nitrogen was added n-butyl-lithium (1.1 equivalent)

over a period of 10 minutes. The reaction mixture was stirred for

1.5 hours at -78°C to give a dark green solution. Benzyl bromide

(1.5 ml, 12.6 mmole) was added. The mixture was allowed to warm to

room temperature and stirred overnight. The reaction was quenched

with saturated ammonium chloride solution (10 ml) and stirred for

a few minutes. The organic layer was separated and the solvent
removed. The residue was redissolved in dichloromethane (100 ml),
washed with water (2 x 25 ml) and dried. Removal of the solvent and
column chromatography on alumina (60g), eluting with dichloromethane,
chloroform and eventually chloroform-methanol, gave an oil which was
a mixture of the two sulphones (66b) and (67b) (0.4g, 38%), ν_{max}
(CH_2Cl_2) 1315, 1125 and 815 cm^{-1}, $\delta(CDCl_3)$ 7.95-6.75 (11H,m); 4.97
(0.62H,t,J=5.25 Hz); 4.70-2.90 (4.38 H,m), m/e 308, 244, 243, 229.

Attempted Separation of Sulphones (66b) and (67b)

The mixture (0.4g) was eluted through a chromatography column of
t.l.c. grade silica (18g), eluting with petrol-dichloromethane and
collecting 20 ml fractions. 15 Fractions containing the products
were collected but all were mixtures of the two isomers. However,
the fifteenth fraction contained a considerable excess of one isomer
and gave the following ^1H n.m.r. spectrum to a close approximation:
$\delta(CDCl_3)$ 8.10-7.30 (11H,m); 5.17 (1H,t,J=6 Hz); 4.03, 3.77 (2H, d of
J=15 Hz); 3.46 (1H,d,J=6 Hz); 3.33 (1H,d,J=6 Hz).

1,3-Dihydro 1-(prop-4-enyl)naphtho [1,2-c]thiophene 2,2-Dioxide
(67a) and its 3-(prop-4-enyl) Isomer (66a)

(a)   Using n-Butyl-Lithium: To a stirred solution of 1,3-dihydro-
naphtho[1,2-c]thiophene 2,2-dioxide (0.5g, 2.29 mmole) in dry THF
(60 ml) at -78°C under an atmosphere of dry nitrogen was added n-
butyl-lithium (1.1 equivalent) over a period of 10 minutes. The
reaction mixture was stirred for 1.5 hours at -78°C to give a dark
green solution and the 5-bromopent-1-ene (0.35 ml, 2.96 mmole) was

added. The mixture was allowed to warm to room temperature and stirred overnight. Saturated sodium chloride solution (10 ml) was added and the mixture stirred for a few minutes. The organic layer was separated and the solvent removed. The residue was redissolved in dichloromethane (100 ml), washed with water (50 ml) and dried. Removal of the solvent and chromatography on silica M.F.C. (23g), eluting with dichloromethane gave a mixture of the sulphones (66a) and (66b) (0.15g, 23%), ν_{max} (nujol) 2910, 1305, 1118 and 805 cm^{-1}, δ(CDCl$_3$), 7.97-7.16 (6H,m); 6.00-5.50 (1H,m); 5.20-4.82 (2H,m); 4.80-4.55 (1.35H, m); 4.53-4.20 (1.65H, m); 2.80-1.40 (6H,m), m/e 286, 22, 181.

(b)   Using LDA: Using the general method described for (a) the anion of the sulphone (21) (0.5g, 2.29 mmole) was generated using LDA (1.1 equivalent). The mixture was warmed to room temperature to ensure complete conversion to the anion, then recooled to -78°C before addition of the 5-bromopent-1-ene (0.6 mol, 5.07 mmole). Work up and chromatography on alumina (10g) gave a mixture of the alkylation products as before (0.25g, 37%). Analytical data approximately as for (a).

(c)   Using LDA and HMPT: The general method described for (a) and (b) was used, but with the addition of HMPT (0.06 ml) to the solution of the sulphone (0.27g, 1.24 mmole) before addition of the base. LDA (1 equivalent) was added over 15 minutes and the reaction mixture stirred at -78°C for 40 minutes to give a dark brown solution before addition of the 5-bromopent-1-ene (0.6 ml, 5.07 mmole). Work up and chromatography on alumina (20g), eluting with petrol-dichloromethane

gave a mixture of the alkylation products (0.3g, 84%), δ(CDCl$_3$) 7.97-

7.16 (6H,m); 6.00-5.50 (1H,m); 5.20-4.82 (2H,m); 4.80-4.56 (1.46H,m);

4.53-4.20 (1.54H,m); 2.80-1.40 (6H,m).

Attempted Separation of Sulphones (66a) and (66b)

A mixture of these two sulphones was eluted through a chromatography

column of t.l.c. grade silica (10g) using petrol-dichloromethane as

elutant and taking 10 ml fractions. This procedure failed to separate

the two compounds.

Elution with dichloromethane-petrol through a chromatography column

of silica M.F.C. (10g), impregnated with 10% silver nitrate solution

and dried at 100°C also failed to separate the two sulphones.

The mixture gave one spot or, at best two overlapping spots, on all

t.l.c. systems tried.

Thermolysis of 1,3-dihydro-1-(pent-4-enyl)naphtho[2,3-c]thiophene 2,2-Dioxide (57b)

(a)   A solution of the sulphone (57b) (0.125g, 0.45 mmole) in 1,2,4-

trichlorobenzene (5 ml) was heated under reflux in an atmosphere of

argon for 3 hours. On cooling the solvent was removed by warming

under vacuum. Recrystallisation of the residue from chloroform-petrol

gave a nearly quantitative recovery of the starting material.

(b)   A solution of (57b) (0.048g, 0.17 mmole) in dry diethyl phthalate

(4 ml) was heated under reflux for 20 minutes in an atmosphere of

nitrogen. On cooling the solution was poured into 2M sodium hydroxide (40 ml) and warmed gradually with stirring in a distillation apparatus until the temperature of the vapour reached 100°C. The mixture was cooled to room temperature and extracted with dichloromethane (3 x 20 ml). The organic layers were combined, washed with water (30 ml) and dried. Removal of the solvent, chromatography on alumina (5g), eluting with petrol, and sublimation at 0.05 mm/Hg (oven temperature 100-120°C) gave 1,2,3,4-tetrahydro-1,2-cyclopentenoanthracene (62), (0.02g, 54%), m.p. (sublimed) 70-74°C, ν_{max} (CH_2Cl_2) 2930, 2880, 1495 and 895 cm^{-1}, δ($CDCl_3$) 7.76-7.02 (6H,m); 3.38-0.68 (12H,m), m/e 222, 194, 193, 181, 179, 166, 165, $C_{17}H_{18}$ requires C, 91.84; H, 8.16, Found: C, 92.02; H, 8.14.

(c) Using the method described for (b) above, a further quantity of sulphone (0.12g, 0.42 mmole) was thermolysed. Purification by preparative t.l.c. on silica gave 1,2,3,4-tetrahydro-1,2-cyclopentenoanthracene (0.0174g, 19%) and a constitutional isomer, believed to be 2-(hexa-1,5-diene)-3-methylnaphthalene (2.4 x 10^{-3}g) δ($CDCl_3$) 7.78-7.10 (6H,m); 6.30-4.65 (5H,m); 2.40 (3H,s); 2.38-1.70 (4H,m), m/e 222, 181, 166, 165. This compound was also detectable by t.l.c. in the crude product from (b) above.

Attempted Photolysis of 1,3-Dihydro-1-(pent-4-enyl)naphtho
[2,3-c]thiophene 2,2-Dioxide (57b)

A solution of the sulphone (57b) (0.1g, 0.35 mmole) in deoxygenated methanol (40 ml) was irradiated at 254 nm for 21 hours. Removal of the solvent and analysis of the residue by t.l.c. and [1]H n.m.r. showed only starting material to be present.

Thermolysis of a Mixture of 1,3-dihydro-1-(pent-4-enyl)naphtho [1,2-c]thiophene 2,2-dioxide (67a) and its 3-(pent-4-enyl) Isomer (66a)

A solution of a mixture of the title sulphones (67a) and (66a), (0.25g), in diethylphthalate (5 mls) was heated under reflux for 15 minutes. On cooling the solution was poured into 2M sodium hydroxide (50 ml) in a distillation apparatus and heated gradually with stirring until the temperature of the vapour reached 100°C. The mixture was then cooled to room temperature and extracted with dichloromethane (3 x 25 ml). The organic layers were combined, washed with water (40 ml), dried and evaporated. Chromatography on silica (8g) impregnated with silver nitrate (0.8g), eluting with petrol-dichloromethane, followed by further chromatography on t.l.c. grade silica (6g), eluting with petrol, gave a mixture of two compounds, believed to be the hydrocarbons (68) and (69), (0.06g, 31%), b.p. 65-70°C at 0.1 mm/Hg, δ(CDCl$_3$) 8.15-6.97 (6H,m); 3.70-0.90 (12H,m), m/e 222, 193, 165, 141. Analysis by g.l.c. (3% OV 17, 209°C, flow pressure 9 psi) showed two overlapping peaks (retention times 27 minutes, 24 seconds and 29 minutes 48 seconds). A further product was collected from the first chromatography column; this product may have been a mixture of 1-(hex-1,5-diene)2-methylnaphthalene (70) and 2-(hex-1,5-diene)-1-methylnaphthalene (71) (0.04g, 21%), δ(CDCl$_3$) 8.20-7.16 (6H,m); 6.65 (1H,d,J=16 Hz); 6.20-5.50 (2H,m); 5.30-4.75 (2H,m); 2.62-2.10 (7H,m).

4-Phenyl-m-dioxane(98)

4-Phenyl-m-dioxane was prepared in 90% yield using styrene, aqueous formaldehyde and sulphuric acid, as described by Shortridge[54], b.p. 98°C at 1.0 mm/Hg (lit.[54] 121-123°C at 11 mm/Hg), $\delta(CDCl_3)$ 7.29 (5H,s); 5.11, 4.74 (2H,d of d, J=6Hz); 4.65-3.50 (3H,m); 2.25-1.40 (2H,m).

1,3-Dichloro-1-phenylpropane (99)

The following reaction conditions have been previously described in whole or in part by Shorygina[53]:

(a) A solution of 4-phenyl-m-dioxane (130g, 0.79 mole) in carbon tetrachloride (200 ml) was added slowly to a suspension of phosphorus pentachloride (340g, 1.63 mole) in carbon tetrachloride (1L). The reaction mixture was stirred at room temperature for approximately 6 weeks and at 40-60°C for approximately 6 days. At the end of this period analysis by g.l.c. indicated that the reaction was incomplete.

(b) 4-Phenyl-m-dioxane (50g, 0.3 mole) was added slowly to a stirred suspension of phosphorus pentachloride (200g, 1.13 mole) in carbon tetrachloride (500 ml) and the reaction mixture stirred at 50-60°C for 32 hours. The solvent was removed and the residue taken up in chloroform (500 ml) and water (500 ml). The organic layer was separated, washed with dilute sodium bicarbonate solution (500 ml) and water (200 ml) and dried. Removal of the solvent gave a yellow oil (70g), containing starting material and products by g.l.c. analysis.

This oil was added slowly to a stirred suspension of zinc chloride

(15g, 0.11 mole) in thionyl chloride (160g, 1.34 mole). The reaction

mixture was stirred overnight at room temperature and then heated at

70-80°C for 1.5 hours. After most of the excess thionyl chloride had

been removed under reduced pressure, it was diluted with ether (500 ml)

and poured into water (500 ml). The organic layer was washed with

dilute bicarbonate solution (500 ml) and water (200 ml), and dried.

Removal of the solvent and distillation gave 1,3-dichloro-1-phenylpropane

(22g, 50%), b.p. 92-95°C at 0.4 mm/Hg (lit.[53] 111-113°C at 3 mm/Hg) δ

(CDCl$_3$) 7.33 (5H,s); 5.12 (1H,t,J=6Hz); 4.00-3.28 (2H,m); 2.68-2.05

(2H,m).

(c) To a stirred suspension of zinc chloride (51g, 0.37 mole) in 4-

phenyl-m-dioxane (300g, 1.83 mole) was added thionyl chloride (544g,

4.57 mole) and the mixture stirred at room temperature overnight. It

was then heated gently under reflux for 4 hours. The reaction was

followed by g.l.c. and the appearance of another compound of greater

retention time was observed. After 1.5 hours of heating under reflux

the reaction appeared to be less than half complete. Work up as

described for (b) gave a black tar which on distillation gave a very

small amount of the desired product (<5g, <2%).

2-Phenylthietan (97)

1,3-Dichloro-1-phenylpropane (45.3g, 0.24 mole) was added dropwise

over a period of 1.5 hours to a refluxing solution of sodium sulphide

nonahydrate (86g, 0.36 mole) in water (80 ml) and ethanol (100 ml).

The reaction mixture was heated under reflux overnight. On cooling

it was diluted with water (200 ml) and extracted with ether (3 x 20 ml). The organic layer was separated, washed with water (200 ml) and dried. Removal of the solvent and distillation gave 2-phenylthietan (19g, 53%) b.p. 74°C at 0.1 mm/Hg (lit.[52] 66°C at 1.5 mm/Hg), $\delta(CDCl_3)$ 7.60-7.10 (5H,m); 4.88 (1H,t,J=8Hz); 3.53-2.74 (4H,m), (lit.[52] $\delta(CCl_4)$ 7.3 (5H,m); 4.78 (1H,t,$J_{ax}+J_{bx}$ = 15.2Hz); 2.75-3.3 (4H,m)).

2-Phenylthietan 1,1-dioxide (89)

To a stirred solution of 2-phenylthietan (13.7g, 0.091 mole) in dichloromethane (100 ml) at 0°C was added, dropwise over 1 hour, a solution of m-chloroperbenzoic acid (40.7g, 0.20 mole) in dichloromethane (500 ml). The reaction mixture was allowed to warm to room temperature and stirred for a further 2.5 hours. It was filtered and the filtrate eluted through alumina (130g), eluting well with chloroform. Recrystallisation gave 2-phenylthietan 1,1-dioxide (12.5g, 75%), m.p. (chloroform-petrol) 82-84°C (lit.[44] m.p. 82-84°C) $\delta(CDCl_3)$ 7.33 (5H,s); 5.43 (1H,t,J=10Hz); 4.25-3.90 (2H,m); 2.70-2.20 (2H,m) (lit.[44] $\delta(CDCl_3)$ 7.57-7.40 (5H,m); 3.52 (1H,t,J=9.5Hz); 4.40-3.92 (2H,m); 2.86-2.17 (2H,m)).

2-Carboxy-2-phenylthietan 1,1-dioxide (103)

To a stirred suspension of 2-phenylthietan 1,1-dioxide (3g, 16.5 mmole) in dry ether (150 ml) at -78°C under an atmosphere of dry nitrogen was added n-butyl lithium (1.1 equivalent), dropwise over 20 minutes. The reaction mixture was stirred for a further 40 minutes at -78°C to give a green solution, then dry carbon dioxide was

bubbled through, immediately causing a white precipitation. On warming to room temperature the mixture was filtered, and the precipitate washed with ether (50 ml) to give the lithium salt of 2-carboxy-2-phenylthietan 1,1-dioxide (3.4g, 89%). Treatment with dilute sulphuric acid, extraction into dichloromethane, drying and removal of the solvent gave the acid (103) quantitatively, m.p. (chloroform-petrol) 158-166°C, δ(d6-DMSO) 7.38 (5H,s); 4.40-3.93 (2H,m); 3.20-2.37 (2H,m); 5.50-3.50 (1H,s,broad), ν_{max}(CH$_2$Cl$_2$) 3060, 1750, 1715, 1335, 1175 and 1135 cm^{-1}, m/e 181, 162, 117.

2-Methoxycarbonyl-2-phenylthietan 1,1-dioxide (104)

To a solution of 2-carboxy-2-phenylthietan 1,1-dioxide (1g, 5.49 mmole) in absolute methanol (8 ml) at 0°C was added dropwise an ethereal solution of diazomethane until the reaction mixture became pale yellow. Removal of the solvent and recrystallisation gave (104) (0.7g, 66%) m.p. (chloroform-petrol) 92-94°C, δ(CDCl$_3$) 7.35 (5H,s); 4.43-3.83 (2H,m); 3.75 (3H,s); 3.35-3.00 (1H,m); 2.87-2.40 (1H,m), ν_{max}(CH$_2$Cl$_2$) 1735, 1430, 1330, 1240, 1215, 1172, 1135 and 800 cm^{-1}, m/e 181, 176, 117, 105, C$_{11}$H$_{12}$O$_4$S requires C, 54.99; H, 5.03; S, 13.34, Found: C, 55.04; H, 4.99; S, 13.35.

2-Ethoxycarbonyl-2-phenylthietan 1,1-dioxide (102)

n-Butyl-lithium (1.1 equivalent) was added dropwise over 10 minutes to a stirred suspension of 2-phenylthietan 1,1-dioxide (1.14g, 6.26 mmole) in dry ether (40 ml) at -78°C under an atmosphere of dry

nitrogen. The reaction mixture was stirred at -78°C for a further 10 minutes then allowed to warm to room temperature. It was recooled to -78°C to give a green solution. Ethyl chloroformate (1.05g, 9.68 mmole) was added over 10 minutes and the reaction mixture allowed to warm gradually to room temperature, then stirred for a further 2 hours.

The reaction was quenched with water (20 ml) and stirred for a few minutes. The organic layer was separated, washed with water (20 ml) and dried. Removal of the solvent gave a clear oil. Attempts at crystallisation failed, but chromatography on alumina (24g), eluting with dichloromethane (contact time 30-60 minutes) gave (102) (0.21g, 18%), m.p. (chloroform-petrol) 71-72°C, $\nu_{max}(CH_2Cl_2)$ 1730, 1339, 1240, 1210, 1170 and 1132 cm^{-1}, $\delta(CDCl_3)$ 7.33 (5H,s); 4.57-3.81 (4H,m); 3.43-2.34 (2H,m); 1.33 (3H,t,J=7Hz), m/e 190, 181, 162, 144, 117, 115, $C_{12}H_{14}O_4S$ requires C, 56.68; H, 5.55, Found C, 56.72; H, 5.50.

Numerous other attempts to prepare (102) by the above method gave, after chromatography on either alumina or silica, seemingly inseparable mixtures of the desired compound and 2-phenylthietan 1,1-dioxide.

Chromatography of 2-Methoxycarbonyl-2-phenylthietan 1,1-dioxide (104)

Elution of a sample of (104) through silica with a contact time of greater than 20 minutes gave, on analysis by t.l.c. and ^{1}H n.m.r. spectroscopy, a mixture of the starting ester (104) and 2-phenylthietan 1,1-dioxide.

Photolysis of 2-Methoxycarbonyl-2-phenylthietan 1,1-dioxide (104)

A solution of (104) (150 mg, 0.62 mmole) in deoxygenated dichloromethane (25 ml) was irradiated at 254 nm for 10 hours. Removal of the solvent and chromatography on silica (2g), eluting with dichloromethane, gave methyl 1-phenylcyclopropane carboxylate (0.09g, 82%) which was identified by comparison of its ^{1}H n.m.r. spectrum with that published, δ(CDCl$_3$) 7.67-7.13 (5H,m); 3.55 (3H,s); 1.77-1.50 (2H,m); 1.33-1.13 (2H,m), (lit.[62] δ(solvent not given) phenyl protons, 3.65 (3H,s); 1.65 (2H,m); 1.24 (2H,m)).

Photolysis of 2-Ethoxycarbonyl-2-phenylthietan 1,1-dioxide (102)

A solution of (102) (100 mg, 0.39 mmole) in deoxygenated dichloromethane (20 ml) was irradiated at 254 nm for 2.5 hours. Removal of the solvent gave crude ethyl 1-phenylcyclopropane carboxylate in quantitative yield (74.2 mg), δ(CDCl$_3$) 7.50-7.07 (5H,m); 4.02 (2H,q,J=7.5Hz); 1.70-1.37 (2H,m); 1.33-0.93 (5H,m), m/e 190, 162, 144, 117, 115.

2-(2-Methylpropan-1-ol)2-phenylthietan 1,1-dioxide (100b)

n-Butyl-lithium (1.1 equivalent) was added dropwise over 10 minutes to a stirred suspension of 2-phenylthietan 1,1-dioxide (0.98g, 5.38 mmole) in dry ether (50 ml) at -78°C under an atmosphere of dry nitrogen. The reaction mixture was allowed to warm gradually to room temperature and then recooled to -78°C to give a brown solution. Isobutyraldehyde (0.5g, 6.93 mmole) dissolved in dry ether (10 ml) was added dropwise over 10 minutes. The reaction mixture was allowed to warm gradually to room temperature and stirred for a further 1 hour. The reaction was quenched with saturated ammonium chloride solution (10 ml) and stirred for a few minutes. The organic layer was separated, washed with water (30 ml) and dried. Removal of the solvent and recrystallisation gave (100b) (0.48g, 35%), m.p. (chloroform-petrol) 98-130°C, ν_{max}(CH$_2$Cl$_2$) 3550, 2955, 1302, 1173, 1125 and 690 cm^{-1}, δ(CDCl$_3$) 7.62-7.13 (5H,m); 4.47-3.70 (3H,m); 3.42-2.30 (3H,m); 1.55-1.08 (1H,m); 1.03-0.67 (6H,m), m/e 190, 182, 162, 147, 116, 115, 103, 91, C$_{13}$H$_{18}$O$_3$S requires C, 61.39; H, 7.13, Found: C, 61.66; H, 7.10. [*diastereoisomers present]

2-(Ethan-1-ol)2-phenylthietan 1,1-dioxide (100a)

(a) n-Butyl-lithium (1.2 equivalent) was added dropwise over 10 minutes to a stirred suspension of 2-phenylthietan 1,1-dioxide (0.96g, 5.27 mmole) in dry ether (50 ml) at -78°C under an atmosphere of dry nitrogen. The reaction mixture was stirred at -78°C for a further 30 minutes, then acetaldehyde (1 ml, 18 mmole) was added dropwise. The reaction mixture was allowed to warm gradually to room temperature and stirred overnight. Saturated ammonium chloride solution (20 ml)

was added and the mixture stirred for a few minutes. The organic layer was separated, and the aqueous layer extracted further with ether (30 ml). The organic layers were combined, washed with water (30 ml) and dried. Removal of the solvent and chromatography on alumina (60g), eluting with chloroform-methanol, gave (100a) (0.35g, 30%) m.p. (chloroform petrol) 88-95°C, $\nu_{max}(CH_2Cl_2)$ 3560, 3050, 1310, 1260, 1180, 1130 and 1100 cm^{-1}, the ^1H n.m.r. spectrum showed two diastereoisomers, $\delta(CDCl_3)$ 7.50-7.03 (5H,m); 4.70-4.33 (1H,m); 4.30-3.70 (2H,m); 3.40 (1H,d,J=4Hz, broad, exchangeable D_2O); 2.93-2.28 (2H,m); 0.93 (3H,d,J=7Hz) and 7.50-7.03 (5H,m); 4.70-4.33 (1H,m); 4.30-3.70 (2H,m); 3.10 (1H,d,J=6Hz, broad, exchangeable D_2O); 2.93-2.28 (2H,m); 1.06 (3H,d,J=6Hz), m/e 182, 162, 144, 134, 133, 118, 117, 105, 91, $C_{11}H_{14}O_3S$ requires C, 58.40; H, 6.24; S, 14.14, Found: C, 58.22; H, 6.21; S, 13.96.

(b) With other reagents and conditions remaining the same as described above, a solution of 2-phenylthietan 1,1-dioxide (0.67g, 3.68 mmole) in dry THF (50 ml) gave (100a) (0.19g, 23%).

Attempted Dehydration of 2-(2-methylpropan-1-ol)-2-phenylthietan 1,1-dioxide (100b)

(a) Using the general method described by Monson and Priest[60], a solution of (100b) (0.1g, 3.39 mmole) in HMPT (4 ml) was heated under reflux for 2 hours. Work up gave an oil, which by t.l.c. analysis consisted of a large number of compounds, most the them very polar.

(b) This general method has been previously described by Appel and

Wihler[62]. To a solution of (100b) (0.1g, 0.39 mmole) and triphenylphosphine

(0.13g, 0.49 mmole) in acetonitrile (10 ml) heated under reflux was

added carbon tetrachloride (0.075g, 0.49 mmole). The reaction mixture

was heated under reflux overnight. Removal of the solvent and

chromatography on alumina (4g), eluting with ether-petrol, gave a

nearly quantitative recovery (0.08g) of the starting material. None

of the desired olefinic product was isolated.

Attempted Preparation of 2-Methoxycarbonyl-4-(2-methylpropan-1-ol) 2-phenylthietan 1,1-dioxide (107)

(a) A solution of LDA (1.1 equivalent) in dry ether was added dropwise

over 10 minutes to a stirred suspension of 2-methoxycarbonyl-2-phenyl-

thietan 1,1-dioxide (104) (0.4g, 1.67 mmole) in dry ether (60 ml) at -

78°C under an atmosphere of dry nitrogen. The reaction mixture was

stirred at -78°C for 10 minutes, then allowed to warm to room

temperature and stirred for 15 minutes. The mixture remained a

suspension but with a yellow tinge. It was recooled to -78°C and

isobutyraldehyde (1 ml, 11 mmole) was added. The mixture was allowed

to warm to room temperature to give a green solution and stirred for

a further 3 hours. The reaction was quenched with saturated ammonium

chloride solution (10 ml) and stirred for a few minutes. The aqueous

layer was extracted further with dichloromethane (50 ml) and the

organic layers were combined and dried. Analysis by t.l.c. showed a

large number of compounds, none of which were identifiable.

Chromatography on silica (16g), eluting with petrol-dichloromethane-

methanol (contact time less than .5 hour) failed to isolate any

identifiable compounds.

(b) Using the general method described above, a solution of the sulphone (104) (0.5g, 2.08 mmole) in THF gave a pale green solution after treatment with LDA (1.1 equivalent). Isobutyraldehyde (0.6 ml, 6.6 mmole) was added and the reaction mixture allowed to warm to room temperature and stood overnight.

Saturated ammonium chloride solution (10 ml) was added and the mixture stirred for a few minutes. The organic layer was separated and the solvent removed. The residue was taken up in dichloromethane (50 ml), washed with water and dried. The solvent was removed and the residue kept at 0.1 mm/Hg for 3 hours. Chromatography on silica M.F.C. (10g), eluting with petrol-dichloromethane-chloroform-methanol (contact time less than .5 hour) failed to isolate any identifiable compounds.

Attempted Preparation of 2-(2-Methylpropan-1-ol)thietan 1,1-dioxide

n-Butyl-lithium (1.1 equivalent) was added to a solution of thietan 1,1-dioxide (2g, 18.9 mmole) and HMPT (0.1 ml, 0.6 mmole) in dry ether (60 ml) at -78°C under an atmosphere of dry nitrogen to give a gelatinous reaction mixture. The reaction mixture was allowed to warm to room temperature, stirred for 25 minutes, then recooled to -78°C. Isobutyraldehyde (7 ml, 77 mmole) was added, giving a pale green solution. The mixture was allowed to warm to room temperature and stirred for 5 hours. Saturated ammonium chloride solution (10 ml) was added and the mixture stirred for a few minutes. The organic layer was separated, washed with water (60 ml) and dried. Removal

of the solvent gave an oil which consisted of a considerable number of compounds by t.l.c. analysis. Chromatography on alumina (100g), eluting with dichloromethane-chloroform-methanol, failed to yield any identifiable compounds apart from HMPT.

2-Carboxythietan 1,1-dioxide (109)

A solution of LDA (1.1 equivalent) in THF (10 ml) was added dropwise over 5 minutes to a suspension of thietan 1,1-dioxide (0.88g, 8.30 mmole) in dry ether (60 ml) at -78°C under an atmosphere of dry nitrogen. The reaction mixture was stirred at -78°C for 35 minutes to give a gelatinous suspension. Dry carbon dioxide was bubbled through and the mixture warmed to room temperature. 1M Sulphuric acid (30 ml) was added; the organic layer separated and the aqueous layer further extracted with ethyl acetate (40 ml). The organic layers were combined and dried. Removal of the solvent and chromatography on silica M.F.C. (10g), eluting with chloroform-methanol, gave a few mgs of (109) δ(d6-DMSO) 5.40 (1H,t,J=9Hz); 4.50-3.95 (2H,m); 2.60-2.00 (2H,m).

CHAPTER THREE

2,2-Dimethyl-1,3-ditosylpropane (146)

Preparation of the ditosylate (146) was accomplished in yields of
91-97% by the reaction of 2,2-dimethyl-1,3-propanediol with tosylchloride
(2.3 equivalent) in pyridine[125], m.p. 108-114°C (lit.[125] m.p. 124°C;
an alternative lit. m.p. value has been given as 66-67°C[127]).

3,3-Dimethylthietan (144)

3,3-Dimethylthietan was prepared using the method described by
Newman et al[89] except that the ditosylate (146) was used instead of
the dimesylate (145).

In a typical procedure a solution of sodium sulphide nonahydrate
(173g, 0.72 mmole) in ethanediol (400 ml) was azeotroped dry by
heating in a flask fitted with a Dean-Stark apparatus until the
boiling point of ethanediol was reached.

On cooling, this solution was added to a warm suspension of the
ditosylate (150g, 0.36 mmole) in ethanediol (300 ml) and the reaction
mixture was heated gradually with continuous stirring in a distillation
apparatus over a period of 2 hours, until no more thietan appeared to
be distilling. The mixture of 3,3-dimethylthietan and ethanediol
collected was separated into its two immiscible components and the
thietan was dried over the minimum amount of magensium sulphate,
(25g, 67%), b.p. 115-117°C (lit.[89] b.p. 115-117°C) $\delta(CDCl_4)$ 2.93
(4H,s); 1.27 (6H,s).

3,3-Dimethylthietan 1,1-dioxide (141)

A solution of 85% m-chloroperbenzoic acid (130g, 0.64 mole) in dichloromethane (1200 ml) was added with stirring to a solution of 3,3-dimethylthietan (31.1g, 0.3 mole) in dichloromethane at 0°C over 2 hours. The reaction mixture was allowed to warm to room temperature and stirred overnight. It was filtered, first through filter paper, then through alumina (200g) washing well, on both occasions with dichloromethane. Removal of the solvent and recrystallisation afforded 3,3-dimethylthietan 1,1-dioxide, (38.6g, 94%), m.p. (ether-40/60 petrol) 52-53°C (lit. m.p. 54-55°C), δ(CDCl$_3$) 3.87 (4H,s); 1.47 (6H,s).

2-(2-Methylpropan-1-ol)3,3-dimethylthietan 1,1-dioxide (147a)

(a) n-Butyl-lithium (1.1 equivalent) was added dropwise over 15 minutes to a stirred suspension of 3,3-dimethylthietan 1,1-dioxide (10g, 75 mmole) in dry THF (125 ml) at -78°C under an atmosphere of dry nitrogen. The mixture was stirred for a further 15 minutes at -78°C to give an amber solution. Isobutyraldehyde (14 ml, 150 mmole) was added dropwise over a few minutes. The reaction mixture was allowed to warm to room temperature and stirred for a further 2 hours.

Saturated brine (10 ml) was added to quench the reaction and the mixture was stirred vigorously for a few minutes. The organic layer was separated and the solvent removed. The residue was redissolved in dichloromethane (200 ml), washed with water (2 x 50 ml) and dried. Removal of the solvent gave a gummy solid. Successive chromatography on silica (360g) then t.l.c. grade silica (360g), eluting through

both with chloroform-methanol gave (147a) (5.26g, 34%) m.p. (chloroform-petrol) 104-114°C, ν_{max}(CH$_2$Cl$_2$) 3600, 2960, 1310, 1265, 1185 and 1105 cm^{-1} δ(CDCl$_2$) 4.26-3.65 (4H,m); 2.68 (1H,d,J=7Hz); 2.10-1.62 (1H,m); 1.50 (6H,s); 1.15 (3H,d,J=7Hz); 1.05 (3H,d,J=6Hz), m/e 206, 163, 134, 119, 107, 99, C$_9$H$_{18}$O$_3$S requires C, 52.40; H, 8.79, Found: C, 52.32; H, 8.61.

Also isolated was 2,4-bis(2-methylpropan-1-ol)-3,3-dimethylthietan 1,1-dioxide (1.95g, 9%), m.p. (chloroform-petrol) 144-145°C ν_{max}(CH$_2$Cl$_2$) 3605, 3560, 2970, 1468, 1398, 1176, 1102 and 992 cm^{-1}, δ(CDCl$_3$) 3.97 (2H,d,J=6Hz); 3.78 (2H,d of d,J$_1$=6Hz,J$_2$=4Hz); 2.18 (2H,s,broad,exchangeable D$_2$O); 2.03-1.57 (2H,m); 1.41 (6H,s); 1.05 (6H,d,J=3Hz); 0.97 (6H,d,J=3Hz), m/e 278, 235, 217, 189, 163, 153, 111, C$_{13}$H$_{26}$O$_4$S requires C, 56.08; H, 9.41, Found: C, 56.10; H, 9.30.

(b)   Sulphone (147a) was also prepared by the general method described above, using ether as solvent. In a typical procedure n-butyl-lithium (1.1 equivalent) was added dropwise over 10 minutes to a stirred suspension of 3,3-dimethylthietan 1,1-dioxide (6g, 45 mmole) in dry ether (150 mls) at -78°C under an atmosphere of dry nitrogen. The mixture was stirred at -78°C for 20 minutes, warmed gradually to room temperature, then recooled to -78°C to give a pale yellow solution. Isobutyraldehyde (12 ml, 130 mmole) was added dropwise over a few minutes. The reaction mixture was allowed to warm to room temperature and stirred for a further 3 hours. The reaction was quenched with water (50 mls) and the organic layer separated, washed with water (50 ml) and dried. Removal of the solvent, chromatography on alumina

(160g), eluting with dichloromethane then increasing concentrations of methanol in chloroform, and recrystallisation afforded (147a) (2.5g, 27%).

(c)   Using the general method described for (a) and (b) above, the addition of HMPT after that of n-butyl-lithum gave a depressed yield (7%) of (147a); the addition of HMPT before that of n-butyl-lithum gave no improvement in yield over the original method (23%).

3,3-Dimethyl-2-(2,2,2-trichloroethanol)thietan 1,1-dioxide (147b)

n-Butyl-lithium (1 equivalent) was added dropwise over 10 minutes to a stirred suspension of 3,3-dimethylthietan 1,1-dioxide (5.6g, 42 mmole) in dry THF (100 ml) at -78°C under an atmosphere of dry nitrogen. The mixture was stirred for a further 30 minutes at -78°C to give a brown solution. Anhydrous chloral (5 ml, 52 mmole) was added dropwise over a few minutes to give a dark brown reaction mixture. The mixture was stirred at -78°C for a further 1 hour, then allowed to warm to room temperature and stirred for a further 1.5 hours.

The reaction was quenched with saturated brine (30 ml) and the aqueous layer separated and extracted further with ether (20 ml) and chloroform (20 ml). The organic extracts were combined and dried. Removal of the solvent and chromatography on silica (180g), eluting with dichloromethane then increasing concentrations of methanol in chloroform gave (147b) (3.5g, 30%), m.p. (chloroform-petrol) 195-200°C, ν_{max} (Nujol) 3410, 1310, 1190, 1155, 1130, 1075, 815 and 755 cm^{-1}, δ(CDCl$_3$) 4.65, 4.23 (2H,d,d of d,J=10Hz); 3.83, 3.60

(2H,d of d, J=12Hz); 3.30-2.70 (1H,broad,s, exchangeable D_2O); 1.60 (3H,s); 1.50 (3H,s), m/e 281/283/285, 245/247/249, 163, $C_7H_{11}Cl_3O_3S$ requires C, 29.86; H, 3.94, Found: C, 29.89; H, 3.97.

2,2-Dichloroethanal

2,2-Dichloroethanal was prepared in overall 25% yield from triisopropyl phosphite and chloral, _via_ acid catalysed decomposition of diisopropyl 2,2-dichlorovinyl phosphate, as described by Pilgram et al[128], b.p. 83-85°C (lit.[128] b.p. 84-86°C).

2-(2,2-Dichloroethanol)-3,3-dimethylthietan 1,1-dioxide (147c)

n-Butyl-lithium (1.1 equivalent) was added dropwise over 10 minutes to a stirred solution of 3,3-dimethylthietan 1,1-dioxide (1.22g, 9.1 mmole) in dry THF (50 ml) at -78°C under an atmosphere of dry nitrogen. The mixture was stirred for a further 25 minutes at -78°C to give a yellow solution. 2,2-Dichloroethanal (1.5g, 13.3 mmole) was added dropwise over a few minutes. The reaction mixture was allowed to warm to room temperature and stirred for a further 1 hour, to give a dark brown solution. Saturated brine (5 ml) was added to quench the reaction and the mixture was stirred for a few minutes. The organic layer was separated, the solvent removed and the residue redissolved in dichloromethane (100 ml). This was washed with water (2 x 50 ml) and dried. Removal of the solvent and chromatography on silica (20g), eluting with dichloromethane then increasing concentrations of methanol in chloroform, afforded (147c), (0.75g, 33%), m.p. (chloroform-petrol) 93-102°C, ν_{max} (nujol) 3490, 1315, 1195, 1135, 1082, 758 and 738 cm^{-1},

$\delta(\text{CDCl}_3)$ 5.95 (1H,d,J=2Hz); 4.57-4.27 (1H,m); 2.57 (1H,broad d,J=6Hz); 1.49 (6H,s), $\delta(\text{CDCl}_3/\text{D}_2\text{O})$ as above except 4.57-4.27 (1H,m) becomes 4.50 (1H,d of d,J_1=10Hz,J_2=2Hz); 2.57 (1H,d) disappears. m/e 247/249/251, 211/213, 193/195, 169/171, 162, 133, 129. Successive recrystallisation afforded crystals m.p. (chloroform-petrol) 135-137°C, $C_7H_{12}Cl_2O_3S$ requires C, 34.02; H, 4.89, Found: C, 34.05; H, 4.78.

3,3-Dimethyl-2-(2-methyl-1-(dimethyl-t-butylsiloxy)propane) Thietan 1,1-dioxide (150)

To a stirred solution of 3,3-dimethyl-2-(2-methylpropan-1-ol)thietan 1,1-dioxide (1g, 4.9 mmole) in DMF (10 ml) were added, in rapid succession, t-butyldimethylsilyl chloride (0.77g, 5.1 mmole) and imidazole (0.69g, 10.1 mmole) and the mixture was stirred at room temperature for 1 week. Further imidazole (0.33g, 4.9 mmole) and t-butyldimethylsilyl chloride (0.37g, 2.4 mmole) were added and the mixture stirred for a further 2 days. Then the mixture was warmed to 50°C and stirred for 3 days, before being warmed to 60°C and stirred for a further 4 days. On cooling the mixture was poured into water (50 ml) and extracted with ether (3 x 20 ml). The organic layers were combined and dried. Removal of the solvent and recrystallisation afforded (15) (0.75g, 48%) m.p. (petrol) 78-88°C, ν_{max} (CH$_2$Cl$_2$) 2695, 1314, 1190, 1110, 1052 and 838 cm^{-1}, $\delta(\text{CDCl}_3)$ 4.10 (2H,s); 3.70,3.47 (2H,d of d,J=12Hz); 1.85-1.57 (1H,m); 1.37 (6H,s); 1.15-0.85 (15H,m); 0.23 (3H,s); 0.15 (3H,s,), m/e 320, 305, 277, 263, $C_{15}H_{32}O_3S$ Si requires C, 56.13; H, 9.82, Found: C, 56.20; H, 10.06.

3,3-Dimethyl-2-(1-mesyl-2-methylpropane)thietan 1,1-dioxide (149)

To a solution of 3,3-dimethyl-2-(2-methylpropan-1-ol)thietan 1,1-dioxide (0.53g, 2.57 mmole) in dry pyridine (8 ml) was added methanesulphonyl chloride (0.6 ml, 7.75 mmole) and the mixture left to stand at room temperature for 5 hours. Further methanesulphonyl chloride (0.2 ml, 2.59 mmole) was added and the mixture left to stand at 40°C for 2 hours. The mixture was filtered and the solvent removed. The residue was redissolved in ether (30 ml), washed with water (15 ml) and dried. Removal of the solvent and recrystallisation afforded (149), (0.43g, 59%) m.p. (chloroform-petrol) 108-114°C, ν_{max} (CH$_2$Cl$_2$) 1350, 1172 and 715 cm^{-1}, δ(CDCl$_3$) 5.08 (1H,d of d, J$_1$=10Hz,J$_2$<3Hz); 4.24, 4.10 (1H,2d,J=10 Hz); 3.86, 3.64 (2H,d of d,J=13Hz); 3.17 (3H,s); 2.001.53 (1H,m); 1.43 (6H,s); 1.19 (3H,d,J=7Hz); 1.00 (3H,d, J=7Hz), m/e 241, 189, 177, 163, 135 and 124, C$_{10}$H$_{20}$O$_5$S$_2$ requires C, 42.23; H, 7.09, Found: C, 42.00; H, 6.90.

3,3-Dimethyl-2-(2-methylprop-1-enyl)thietan 1,1-dioxide (152)

A solution of phosphoryl chloride (0.09 ml, 0.97 mmole) in dry pyridine (1 ml) was added to a stirred solution of 3,3-dimethyl-2-(2-methylpropan-1-ol)thietan 1,1-dioxide (0.5g, 2.4 mmole) in dry pyridine (3 ml) at 0°C under an atmosphere of dry nitrogen. The mixture was stirred overnight and then poured into dilute sulphuric acid (20 ml). The aqueous mixture was extracted with dichloromethane (2 x 40 ml) and the organic layer separated and dried. Removal of the solvent and distillation afforded (152) (0.2g, 44%), b.p. 120-124°C/at 0.1 mm

Hg, m.p. (petrol) 67-68°C, ν_{max} (CH_2Cl_2) 2960, 1305, 1182 and 1098 cm^{-1},

δ(CDCl$_3$) 5.35 (1H,d,J=10Hz); 4.77 (1H,d,J=10Hz); 3.78, 3.58 (2H,d of

d,J=13Hz); 1.82 (3H,s); 1.81 (3H,s); 1.36 (3H,s); 1.28 (3H,s), m/e

188, 132, 124, 109, $C_9H_{16}O_2S$ requires C, 57.41; H, 8.56, Found: C,

57.30; H, 8.44.

Elimination of Methanesulphonic Acid from the Mesylate (149)

To a solution of 3,3-dimethyl-2-(1-mesyl-2-methylpropane)thietan

1,1-dioxide (0.2g, 0.7 mmole) in dry THF (10 ml) under an atmosphere

of dry nitrogen was added 1,5-diazobicyclo[5.4.0]undecene-5 (0.12 ml,

0.79 mmole) and the mixture heated under reflux overnight. Further

1,5-diazobicyclo[5.4.0]undecene-5 (0.35 ml, 2.3 mmole) was added and

the reaction mixture heated under reflux for a further 10 hours. It

was then stirred overnight at room temperature. The solvent was

removed and the residue redissolved in dichloromethane (30 ml), washed

with dilute hydrochloric acid (2 x 40 ml) and water (40 ml). The

solution was dried and the solvent removed. Chromatography on silica

M.F.C. (8g) eluting with dichloromethane, and distillation gave a

mixture of 2 compounds (0.061g), b.p. 125-135°C/0.2 mm Hg.

Analysis by t.l.c. and n.m.r. spectroscopy showed the first of

these to be 3,3-dimethyl-2-(2-methylprop-1-enyl) thietan 1,1-dioxide

(t.l.c. rf (CH_2Cl_2) 0.6). The second gave t.l.c. rf (CH_2Cl_2) 0.55,

δ(CDCl$_3$) 5.57 (1H,d,J=12Hz); 3.67 (2H,s); 3.00-2.65 (1H,m); 1.34

(6H,s); 1.10 (6H,J=7Hz). The ratio of the first compound to the

second was 1:4 by ^{1}H n.m.r. spectroscopy.

Attempted Dehydration of (147a) with Polyphosphoric Acid

The alcohol (147a) (0.5g, 2.43 mmole) was dissolved in polyphosphoric acid (6g) and heated at 90°C, with occassional stirring for 3 hours. On cooling the mixture was hydrolysed with water (20 ml) and extracted with chloroform (20 ml). The organic layer was separated, washed with water (20 ml) and dried. Removal of the solvent gave a brown oil. Analysis by t.l.c. showed considerable starting material to be present, along with a large number of other products.

Attempted Dehydration of (147a) with Potassium Bisulphate

The alcohol (147a) (0.05g, 0.24 mmole) was mixed with dried potassium bisulphate (0.05g, 0.36 mmole) and the mixture finely ground. It was sealed in a glass tube and heated at 220°C for 8 hours. On cooling the mixture was taken up in ether (10 ml) and water (10 ml). The organic layer was separated and dried. Removal of the solvent gave a quantitative recovery of starting material.

Attempted Dehydration of (147a) with Anhydrous Copper Sulphate

The alcohol (147a) (0.1g, 0.49 mmole) was mixed with anhydrous copper sulphate (0.1g, 0.63 mmole) and the mixture was finely ground. It was sealed in a galss tube and heated at 170°C for 10 hours. Work up (as described for the above reaction with potassium bisulphate) gave only starting material.

Repetition of this experiment at 220°C and work up gave a black solid. Analysis of this solid by t.l.c. showed that it contained mainly starting material plus some decomposition products which remained on the baseline.

Reaction of (147a) with Thionyl Chloride

Thionyl chloride (0.35g, 2.94 mmole) was added dropwise over a few minutes to a stirred solution of the alcohol (147a) (0.35g, 1.7 mmole) at 0°C. The mixture was warmed to room temperature and stirred for 20 hours. The mixture was then poured into 2M hydrochloric acid (20 ml) which was then extracted with dichloromethane (2 x 20 ml). The organic layers were combined, washed with water (20 ml) and dried. Removal of the solvent gave a crude oil, consisting mainly of two compounds. One of these was identified as 3,3-dimethyl-2-(2-methylprop-1-enyl)thietan 1,1-dioxide (152). The mixture was redissolved in pyridine (5 ml) and stirred at room temperature for 2 days. Work up as before gave an unchanged crude product. Distillation gave (152) (0.07g, 22%) b.p. 120-124°C/0.1 mm Hg. The residue was recrystallised and may be 2-(1-chloro-2-methylpropane)-3,3-dimethylthietan 1,1-dioxide (0.04g), m.p. (chloroform-petrol) 219-240°C ν_{max} (nujol) 1305 and 1110 cm^{-1} δ(CDCl$_3$) 5.05-4.62 (1H,m); 4.48-4.20 (1H,m); 3.82, 3.53 (2H,d of d,J=13Hz); 2.02-1.52 (1H,m); 1.42 (6H,s).

2-(1-Chloro-2-methylpropane)-3,3-dimethyl-4-(2-methylpropan-1-ol) thietan 1,1-dioxide (157)

To 2,4-bis(2-methylpropan-1-ol)3,3-dimethylthietan 1,1-dioxide (0.5g, 1.8 mmole) was added phosphoryl chloride (0.1 ml, 1.1 mmole) in dry pyridine (5 ml) and the mixture stirred overnight at room temperature. It was poured into a mixture of concentrated hydrochloric acid (20 ml), water (20 ml) and ice (20 ml) and extracted with dichloromethane (2 x 60 ml). The organic layers were combined and dried. Removal of the solvent and chromatography on silica (10g),

eluting with dichloromethane-petrol afforded (157), (0.12g, 23%),

m.p. (petrol) 84.5-85.5°C ν_{max} (nujol) 3535, 1398, 1174, 1155, 1102

and 1065 cm^{-1}, δ(CDCl$_3$) 4.27 (1H,d of d,J_1=12Hz,J_2=1Hz); 4.22 (1H,d

of d,J_1=12Hz,J_2=2Hz); 3.67 (1H,d of d,J_1=2Hz,J_2=1Hz); 3.62-3.34

(1H,broad m); 2.69 (1H,broad d,J=9Hz); 2.16 (1H,d of septet,Jd=2Hz,

Js=7Hz); 1.89 (1H,octet,J=7Hz); 1.48 (3H,s); 1.44 (3H,s); 1.02

(3H,d,J=7Hz); 0.98 (3H,d,J=7Hz); 0.96 (3H,d,J=7Hz); 0.93 (3H,d,J=7Hz),

δ(CDCl$_3$/D$_2$O) as above except 3.62-3.34 (1H,broad m) collapses, 2.69

(1H,broad d) disappears, m/e 255/253, 145/143, 111, 109, ^{13}C n.m.r.

(CDCl$_3$) 85.05 (d), 84.98 (d), 73.77 (d), 62.08 (d), 33.29 (d), 31.92

(d), 31.82 (s), 23.92 (q), 23.79 (q), 20.45 (q), 19.61 (q), 18.29

(q), 15.13 (q), C$_{13}$H$_{25}$ClO$_3$S requires C, 52.60; H, 8.49, Found: C,

52.64; H, 8.35.

2-(2,2-Dichloroprop-1-enyl)-3,3-dimethylthietan 1,1-dioxide (155)

To 2-(2,2-dichloropropan-1-ol)3,3-dimethylthietan 1,1-dioxide (0.3g,

1.2 mmole) was added phosphoryl chloride (0.22 ml, 2.4 mmole) in dry

pyridine (18 ml) and the mixture stirred at room temperature for 2

days. It was poured into 3M hydrochloric acid (50 ml) and the aqueous

mixture extracted with dichloromethane (2 x 40 ml). The organic

layers were combined, washed with saturated sodium bicarbonate solution

(20 ml) and water, and dried. Removal of the solvent and recrystallisation

afforded (155) (0.14g, 50%), m.p. (petrol) 47-50°C, ν_{max}(CH$_2$Cl$_2$)

2970, 1615, 1320, 1190, 1160, 1128, 1100 and 925 cm^{-1}, δ(CDCl$_3$) 6.16

(1H,d,J=9Hz); 4.90 (1H,d,J=9Hz); 3.88, 3.68 (2H,d of d,J=13Hz); 1.46

(3H,s); 1.32 (3H,s), m/e 176/174/172, 168/166/164, 153/151/149, 131,

129, $C_7H_{10}Cl_2O_2S$ requires C, 36.70; H, 4.40; Cl, 30.95, Found: C, 36.67; H, 4.34; Cl, 31.24.

Attempted Preparation of 2-(2,2-dichloroepoxyethane)-3,3-dimethyl-thietan 1,1-dioxide (156)

(a)   A solution of 3,3-dimethyl-2-(2,2,2-trichloroethanol)thietan 1,1-dioxide (147b) (0.2g, 0.71 mmole) and anhydrous sodium acetate (0.2g, 2.4 mmole) in dry acetone (4 ml) was heated under reflux for 4 days. At the end of this period, analysis by t.l.c. showed the starting sulphone to be the only involatile compound present, besides sodium acetate.

(b)   50% Sodium hydride in oil (0.022g, 0.46 mmole) was washed with dry ether (3 ml) and to the remaining solid was added a solution of (147b) (0.1g, 0.36 mmole) in dry DMSO (3 ml). The reaction mixture was warmed slowly to 90°C over a period of 6 hours. By t.l.c. analysis, it was observed that as the temperature increased a number of spots appeared near to the baseline. Starting material was still present but nothing displayed a reference value similar to that expected for the desired product. At room temperature the starting sulphone was the only compound observed to be present.

(c)   Repeating the procedure for (b), but using a catalytic amount of silver nitrate, gave the same result.

2-Carboxy-3,3-dimethylthietan 1,1-dioxide (158)

n-Butyl-lithium (1 equivalent) was added dropwise over 10 minutes to a stirred solution of 3,3-dimethylthietan 1,1-dioxide (2.5g, 18.7 mmole) in dry THF (60 ml) at -78°C under an atmosphere of dry nitrogen.

The mixture was stirred for 15 miutes at -78°C to give a yellow

solution. Dry carbon dioxide was bubbled, causing the immediate

precipitation of a white solid. The reaction mixture was allowed to

warm to room temperature while carbon dioxide was continuously bubbled

through and then filtered. The solid was washed with ether and then

dissolved in 1M sulphuric acid (90 ml). The aqueous solution was

extracted with ether (100 ml) and chloroform (100 ml) and the organic

extracts combined and dried. Removal solvent and recrystallisation

gave (158) (0.61g, 18.4%), m.p. (chloroform-petrol) 128-136°C, ν_{max}

(nujol) 2640-2320, 1710, 1320, 1190, 1155 and 1098 cm^{-1}, $\delta(d_6$-DMSO)

5.11 (s,1H); 3.75, 3.65 (2H,d of d,J=13Hz); 1.38 (6H,s); 5.70-2.70

(1H,s,v.broad).

Considerable crude (158) remained which could not be recrystallised

but was considered suitable for esterification.

3,3-Dimethyl-2-methoxycarbonylthietan 1,1-dioxide (159)

To a solution of 2-carboxy-3,3-dimethylthietan 1,1-dioxide (0.4g,

2.25 mmole) in absolute methanol (10 ml) was added dropwise an etheral

solution of diazomethane until the methanol solution became tinged

yellow. Evaporation of the solvent and recrystalliation afforded

(159) (0.31g, 72%), m.p. (dichloromethane-petrol) 77-78°C, ν_{max}

(CH_2Cl_2) 1745, 1335, 1195, 1150, 1130, $\delta(CDCl_3)$ 4.70 (1H,s); 3.97-

3.62 (5H,m); 1.53 (6H,s), m/e 192, 178, 162, 128, 113, $C_7H_{12}O_4S$

requires C, 43.74; H, 6.29, Found: C, 43.64; H, 6.21.

The above procedure was repeated using the remaining crude acid

previously prepared. Attempts at recrystallisation of the product

failed. Analysis by t.l.c. showed one spot to be dominant, but flash

chromatography on silica (30g), eluting with dichloromethane-petrol

then chloroform, gave an oil (1.6g), identified by n.m.r. spectroscopy

as a mixture of 3,3-dimethylthietan 1,1-dioxide (141) and the ester

(159). This mixture gave only one spot on t.l.c., with a reference

value corresponding to that of (141). Calculation of the relative

amounts by n.m.r. spectroscopy gave values of 1.83g of (159) and

0.53g of (141), corresponding to a yield of 60% in the two steps from

(141) to (159).

2-Carboxy-3,3-dimethyl-4-(2-methylpropan-1-ol)thietan 1,1-dioxide (160)

n-Butyl-lithium (2.1 equivalent) was added dropwise over 15 minutes

to a stirred suspension of 3,3-dimethyl-2-(2-methylpropan-1-ol)thietan

1,1-dioxide (0.77g, 3.74 mmole) in dry ether (75 ml) at -78°C under

an atmosphere of dry nitrogen. The mixture was allowed to warm

gradually to room temperature, then recooled to -78°C and stirred for

a further 15 minutes to give a colourless solution. Dry carbon

dioxide was bubbled through, causing the formation of a white

precipitate. The mixture was warmed to room temperature while carbon

dioxide was continuously bubbled through and then a 1M sulphuric acid

(50 ml) was added, dissolving the precipitate. The organic layer was

separated and the aqueous layer further extracted with ether (60 ml)

and dichloromethane (60 ml). The organic layers were combined and

dried. Removal of the solvent afforded a white solid (160) (0.37g,

40%) which was difficult to recrystallise but was considered suitable for esterification, $_{max}$ (nujol) 3380, 2730-2280, 1715, 1320, 1310, 1170 and 1092 cm^{-1}, m/e 250, 207, 189, 163, 114.

3,3-Dimethyl-2-methoxycarbonyl-4-(2-methylpropan-1-ol)thietan 1,1-dioxide (161)

To a solution of crude acid (160) (0.245g), prepared above, in absolute methanol (5 ml) at 0°C, was added dropwise an etheral solution of diazomethane until nitrogen evolution ceased and the methanol solution became tinged yellow. Evaporation of the solvent and recrystallisation gave (161) (0.2g, 77%, 31% from (147a)), m.p. (chloroform-petrol) 103-110°C, ν_{max} (CH$_2$Cl$_2$) 3605, 2970, 1745, 1465, 1435, 1325, 1210 and 1150 cm^{-1}, δ(CDCl$_3$) 4.67 (1H,s); 4.25-4.03 (2H,m); 3.79 (3H,s); 2.70-2.47 (1H,m); 2.00-1.56 (1H,m); 1.46 (3H,s); 1.39 (3H,s); 1.05 (3H,d,J=6Hz); 0.93 (3H,d,J=6Hz) m/e 264, 249, 221, 203, 171, 115, ^{13}C n.m.r. (CDCl$_3$) 164.1(s); 163.0(s); 86.4(d); 85.1(d); 84.6(d); 81.2(d); 72.8(d); 71.1(d); 52.4(q); 52.35(q); 32.95(s); 32.0(s); 31.9(d); 30.7(d); 29.25(q); 24.85(q); 23.9(q); 19.6(q); 17.8(q); 16.4(q); 14.4(q), C$_{11}$H$_{20}$O$_5$S requires C, 49.98; H, 7.63; S, 12.13, Found: C, 50.02; H, 7.52; S, 12.08.

Attempted Preparation of 2-Carboxy-4-(2,2-dichloroethanol)-3,3-dimethylthietan 1,1-dioxide (162)

(a)   n-Butyl-lithium (2.2 equivalent) was added dropwise over 10 minutes to a solution of 2-(2,2-dichloroethanol)-3,3-dimethylthietan 1,1-dioxide (147c), (0.4g, 1.62 mmole) in dry ether (60 ml) at -78°C under an atmosphere of dry nitrogen, causing the rapid formation of a

white precipitate. The mixture was stirred for 15 minutes at -78°C, warmed to room temperature, recooled to -78°C and stirred for a further 20 minutes. Dry carbon dioxide was bubbled through and the mixture allowed to warm to room temperature. However no change in the reaction mixture was observed during any of these manipulations. On the addition of saturated ammonium chloride (30 ml) the precipitate dissolved. The aqueous layer was extracted further with dichloromethane and the organic layers were washed with water (20 ml), combined and dried. Removal of the solvent gave a very small amount of a gum. Analysis by t.l.c. and n.m.r. spectroscopy did not show any identifiable products. The aqueous layer was also evaporated and analysed but also did not contain any identifiable compounds.

(b) LDA (2.2 equivalent) was added dropwise over 5 minutes to a solution of (147c) (0.5g, 2.02 mmole) in dry THF (40 ml) -78°C under an atmosphere of dry nitrogen. The mixture was stirred for 35 minutes at -78°C to give a yellow solution. Dry carbon dioxide was bubbled through while allowing the mixture to warm to room temperature. 2M Sulphuric acid (5 ml), saturated with sodium chloride, was added and the mixture stirred for a few minutes. The organic layer was separated and the solvent removed. The residue was dissolved in chloroform (100 ml), washed with 2M sulphuric acid (50 ml), water (20 ml) and the aqueous layers reextracted with ether (40 ml). The organic layers were combined and dried and removal of the solvent gave a residual oil. Analysis by t.l.c. and n.m.r. spectroscopy could only identify the starting sulphone, which was the major compound present.

3,3-Dimethyl-2-methoxycarbonyl-2-(2-methylprop-1-enyl)thietan 1,1-dioxide (163)

A solution of phosphoryl chloride (0.15 ml, 1.61 mmole) in dry pyridine (1 ml) was added with stirring to 3,3-dimethyl-2-methoxycarbonyl 2-(2-methylpropan-1-ol)thietan 1,1-dioxide (0.614g, 2.33 mmole) at 0°C over 1 minute. Further dry pyridine was added (1 ml) and the mixture was stirred at room temperature for 4 hours. 1M Sulphuric acid (30 ml) was added and the mixture extracted with dichloromethane (2 x 20 ml). The organic layers were combined and dried. Removal of the solvent and distillation afforded an oil (0.247g), b.p. 120°C 0.02 mm/Hg, δ(CDCl$_3$) (approximated integration values) 5.35 (1H,m); 4.80-4.36 (2H,m); 3.80 (3H,s); 1.83 (3H,s); 1.73 (3H,s); 1.53, 1.43, 1.40, 1.33 (6H,4s), m/e 246, 221, 182, 167, 151, 139, 123, 110. Attempts at recrystallisation failed. The mixture decomposed during analysis by g.l.c. but t.l.c. showed it to contain two major compounds, with reference values corresponding to those for 3,3-dimethyl-2-(2-methylprop-1-enyl)thietan 1,1-dioxide (152) and 4,4-dimethyl-5-(2-methylprop-1-enyl)-1,2-oxathiole 2-oxide (164).

Flash Vacuum Thermolysis of 3,3-dimethyl-2-methoxycarbonylthietan 1,1-dioxide (159)

The sulphone (159) (100 mg) was sublimed through the apparatus at 5 x 10^{-3} mm/Hg with the furnace temperature at 750°C. Analysis by g.l.c. showed one volatile product to predominate, retention time 5 minutes 50 seconds (3% OV17, 80°C, flow pressure 10 psi). Distillation gave a clear oil (29 mg) b.p. 140-146°C. However analysis by g.l.c. now showed a second volatile compound to now be present, retention

time 10 minutes. Preparative g.l.c. 10% OV17, 80°C flow pressure 15 psi, isolated a sample of methyl 2,2-dimethylcyclopropane carboxylate corresponding to the first g.l.c. peak and identified by comparison of its ^{1}H n.m.r. spectrum with that published δ(CDCl$_3$) 3.65 (3H,s); 1.20 (3H,s); 1.15 (3H,s); 1.70-1.40, 1.10-0.72 (3H,m), lit.[102] δ(CCl$_4$) 3.63 (3H,s); 1.19 (3H,s); 1.14 (3H,s); 1.50 (1H,d of d,Jcis=8.1Hz, Jvic=5.1Hz); 0.79 (1H,d of d,Jgem=4.0Hz,Jcis=8.1Hz); 1.05 (1H,d of d,Jgem=4.0Hz, Jvic=5.1Hz).

Using an identical procedure to that described above, but with the furnace temperature at 650-700°C, gave a product mixture (67 mg) of the starting sulphone 9159) and the cyclopropyl ester (165) which, by ^{1}H n.m.r. spectroscopy, were in the molar ratio 1:0.64 respectively. Thus the yield of (165) from unrecovered starting material was 69%.

Attempted Photolysis of (159)

The sulphone (159) (50 mg) was dissolved in deoxygenated dichloromethane (30 ml) and irradiated for 24 hours at 254 nm, giving a brown solution. Removal of the solvent and analysis by ^{1}H n.m.r. spectroscopy and g.l.c. showed starting material to be the main and only identifiable compounds present. The cyclopropyl ester (159) was not detected.

Flash Vacuum Thermolysis of 3,3-dimethyl-2-(2-methylprop-1-enyl) thietan 1,1-dioxide (152)

The sulphone (152) (145 mg) was sublimed through the apparatus at 5×10^{-3} mm/Hg with the furnace temperature at 700°C. Chromatography of the crude product on silica (4g), eluting with dichloromethane-petrol afforded the starting material (15 mg) and 4,4-dimethyl-5-(2-methylprop-1-enyl)oxathiole 2-oxide (164) (38 mg, 29% from unrecovered starting material), $\nu_{max}(CH_2Cl_2)$ 2970, 1675, 1468, 1388, 1120, 1068, 920, 900 and 825 cm^{-1}, m/e 189, 188, 154, 139, 132, 124, 109. ^{1}H n.m.r indicated the presence of two diastereoisomers - $\delta(CDCl_3)$ 5.41 (1H,d,J=9Hz); 5.33-5.10 (1H,m); 3.52, 2.72 (2H,d of d,J=13Hz) 1.90-1.65 (6H,m); 1.15 (3H,s); 0.97 (3H,s) and 5.55-5.35 (1H,m); 4.82 (1H,d,J=10Hz); 3.07, 2.94 (2H,d of d,J=13Hz); 1.90-1.65 (6H,m); 1.30 (3H,s); 1.12 (3H,s), in the ratio 3.6:1 respectively. The crude product had also contained considerable white polymeric material.

The above procedure was repeated with the furnace at 900°C. The crude product consisted mainly of insoluble black tar. Analysis by g.l.c. (10% OV17, 98°C, flow pressure 10 psi) failed to detect either the sulphone (152) or the sultine (164), although a small quantity of volatile compounds was present (retention times 1-3 minutes).

The above procedure was also repeated with the furnace at 450°C. Analysis by t.l.c. indicated the presence of both the sulphone (152) and the sultine (164), but no attempt was made to quantify the relative amounts.

Attempted Photolysis of (152)

The sulphone (152) (80 mg) was dissolved in deoxygenated dichloromethane (30 ml) and irradiated at 254 nm for 20 hours. Analysis by t.l.c. indicated the presence only of starting material and one or more compounds which remained on the baseline.

Flash Vacuum Thermolysis of 2-(2,2-Dichloroprop-1-enyl)-3,3-dimethyl-thietan 1,1-dioxide (155)

The sulphone (135) (78 mg) was sublimed through the apparatus at 5×10^{-3} mm/Hg with the furnace temperature at 700°C to give a very dark oil. Chromatography on silica (4g), eluting with dichloromethane gave starting material (3.5 mg) and 5-(2,2-dichloroprop-1-enyl)-4,4-dimethyloxathiole 2-oxide (166) (10 mg, 13% from unrecovered starting material), ν_{max} (neat) 2970, 1610, 1135, 955 and 860 cm^{-1}, m/e 176/174/172, 168/166/164, 153/151/149, 131, 129. ^{1}H n.m.r. indicated the presence of two diastereoisomers - δ(CDCl$_3$) 6.28, 5.00 (2H,d of d,J=9Hz); 3.22, 2.97 (2H,d of d,J=14Hz); 1.35 (3H,s); 1.25 (3H,s) and 5.90, 5.47 (2H,d of d,J=9Hz); 3.50, 2.78 (2H,d of d,J=14Hz); 1.28 (3H,s); 1.03 (3H,s) in the ratio 1:2.5 respectively.

Flash Vacuum Thermolysis of 3,3-Dimethyl-2-methoxycarbonyl 4-(2,methylprop-1-enyl)thietan 1,1-dioxide (163)

The crude sulphone (163) (124 mg) was sublimed through the apparatus at 5×10 cm^{-3} mm/Hg with the furnace temperature at 750°C. Analysis of the crude product by g.l.c. (10% OV17, 162°C, flow pressure 12 psi) showed 6 main peaks (retention times: 1 minute 30 seconds, 1 minute 45 seconds, 2 minutes 20 seconds, 4 minutes 48 seconds, 6 minutes 42 seconds and 7 minutes 24 seconds).

An authentic sample of methyl-trans-chrysanthemate gave a retention

time of 6 minutes 42 seconds under identical g.l.c. conditions and a

mixture of the crude product and methyl-trans-chrysanthemate gave only

one peak in the region 6-7 minutes, also under identical g.l.c.

conditions. Two of the compounds shown in the crude product g.l.c.

trace were analysed by g.l.c. mass spectrometry. The first (g.l.c.

retention time 4 minutes 48 seconds) gave m/e 182, 167, 150, 139,

123. The second g.l.c. retention time 6 minutes 42 seconds gave m/e

182, 167, 151, 139, 123. The latter mass spectrum was identical with

the mass spectrum of the authentic sample of methyl-trans-chrysanthemate.

The quantity of methyl-trans-chrysanthemate in the crude product

was estimated by making a solution of crude product to a known

concentration and measuring the area of the g.l.c. peak in question

(retention time 4 minutes 48 seconds) for a series of injections.

This was then compared to the area of the peak for a series of

injections of a solution of known concentration of methyl-trans-

chrysanthemate. This gave a value of approximately 9 mg of methyl-

trans-chrysanthemate in the crude product.

CHAPTER FOUR

1,3-Dihydronaphtho[2,3-c]thiophene (173)

A solution of 2,3-bis(bromomethyl)naphthalene (3.25g, 10.4 mmole) in dichloromethane (100 ml) was added to a solution of sodium sulphide nonahydrate (7g, 29.2 mmole) and TBAB (0.25g, 0.78 mmole) in water (100 ml) and the mixture was stirred in the dark overnight. The organic layer was separated, filtered, washed with water (7 x 200 ml) and dried. Removal of the solvent gave (173) (1.92g, 99%) considered suitable for oxidation, m.p. 145-162°C (lit.[7] m.p. 154-163°C) δ(CDCl$_3$) 2.05-2.75 (6H,m); 5.61 (4H,s).

1,3-Dihydronaphtho [1,2-c]thiophene (175)

(a)   A solution of 1,2-bis(bromomethyl)naphthalene (3.15g, 10 mmole) in dichloromethane (100 ml) was added to a solution of sodium sulphide nonahydrate (7g, 29.2 mmole) in water (150 ml). An aqueous 50% solution of CTEAC (1 ml, 1.38 mmole) was then added and the mixture stirred in the dark overnight. The organic layer was separated, washed with water (5 x 200 ml) and filtered through phase-separation filter paper. Removal of the solvent gave a solid (1.6g), m.p. 190°-240°C, δ(CDCl$_3$) 1.70-2.90 (broad m); 5.20-6.60 (broad m), m/e 372, 223, 218, 186, 185, 184, 154. The solid was only very sparingly soluble in most organic solvents. A sample (74 mg) was sublimed (temperature of the oil bath was 100-150°C, pressure 0.05 mm/Hg) to give 1,3-dihydro[1,2-c]thiophene (36 mg, 49% from the dibromide (174)), m.p. 50-60°C (lit.[9] 70-78°C) δ(CDCl$_3$) 1.72-2.88 (6H,m); 5.35-5.45 (2H,m); 5.53-5.63 (2H,m), m/e 186, 185, 184.

(b)   A solution of 1,2-bis(bromomethyl)naphthalene (1g, 3.18 mmole)

in chloroform (140 ml) was added to a solution of sodium sulphide

nonahydrate (3g, 12.5 mmole) in water (120 ml). An aqueous 50%

solution of CTEAC (0.5 ml, 0.69 mmole) was then added and the mixture

heated under reflux with stirring for 2 hours. The organic layer was

separated, washed with water (4 x 120 ml) and dried. Removal of the

solvent gave a solid whose [1]H n.m.r. spectrum included the

characteristically shaped multiplets of 1,3-dihydronaphtho[1,2-c]-

thiophene (175) at δ(CDCl$_3$) 5.35-5.45 and 5.53-5.63. Sublimation

gave (175) (0.08g, 14%) m.p. 52-62°C.

Thiacyclohexan-4-one (180)

    A solution of 1,5-dichloropropan-3-one (4.7g, 30.3 mmole) in

dichloromethane (80 ml) was added to a solution of sodium sulphide

nonahydrate (18g, 75 mmole) in water (120 ml). An aqueous 50% solution

of BTEAC (0.85 ml, 1.87 mmole) was added and the mixture stirred at

35°C for 90 minutes, monitoring the reaction by g.l.c. The mixture

was cooled to room temperature and diluted with dichloromethane (150 ml).

The organic layer was separated, washed with water (6 x 250 ml) and

dried. Removal of the solvent gave (180) (2.55g, 69%), suitable for

oxidation. A sample was sublimed m.p. 64-65°C (lit.[129] 65-66°C),

δ(CDCl$_3$) 3.10-2.84 (4H,m); 2.82-2.57 (4H,m). When the same reactants

were mixed and stirred at room temperature, the reaction was incomplete

after 3 days.

Attempted Preparation of 3,3-dimethylthietan (144)

(a)   A solution of 1,3-dimesyl-2,2-dimethylpropane (3g, 11.5 mmole)

in dichloromethane (30 ml) was mixed with a solution of sodium sulphide

nonahydrate (10g, 41.7 mmole) and TBAB (0.4g, 1.24 mmole) in water

(30 ml) and the mixture stirred at room temperature, monitoring the

reaction by g.l.c. After 1 week the mixture was heated under reflux

for 3 days. On cooling to room temperature the organic layer was

separated and dried. The solvent was removed by distillation at

atmospheric pressure to give a quantitative recovery of the dimesylate.

The reaction was repeated but using chloroform as organic solvent.

The mixture was heated under reflux for 4 days. Work up as before

gave a 33% recovery of the dimesylate. The remainder of the starting

material could be accounted for by decomposition and no desired

product was isolated.

(b)   A solution of 2,2-dimethyl-1,3-ditosylpropane (3g, 7.28 mmole)

in chloroform (50 ml) was added to a solution of sodium sulphide

nonahydrate (6g, 25 mmole) and TBAB (0.3g, 0.93 mmole) in water (60 ml)

and the mixture was heated under reflux with stirring for 2 days. On

cooling to room temperature the organic layer was separated, filtered,

washed with water (4 x 100 ml) and dried. Removal of the solvent

gave a quantitative recovery of the ditosylate.

(c)   A suspension of sodium sulphide nonahydrate (9.3g, 38.8 mmole)

in benzene (250 ml) was heated under reflux in a Dean-Stark apparatus

until all the water had been removed. On cooling, 2,2-dimethyl-1,3-

ditosylpropane (8g, 20.8 mmole) and dicyclohexyl-18-crown-6 (0.35g,

0.94 mmole) were added and the mixture was stirred and heated under reflux for 10 days. On cooling the mixture was filtered, washed with water (2 x 250 ml) and dried. Analysis by g.l.c. (3% OV17, 66°C, flow pressure 10 psi) showed 3,3-dimethylthietan to be present (retention time 2 minutes 30 seconds), but only a small amount (0.2g) could be isolated by distillation owing to the proximity of its boiling point to that of benzene.

This experiment was repeated but using an aqueous sodium sulphide solution instead of sodium sulphide that had been azeotroped dry. The mixture was stirred and heated under reflux for 3 days. Work up gave an 88% recovery of the ditosylate. No 3,3-dimethylthietan was either detected or isolated.

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THE END

SUMMARY

The thermolysis and photolysis of a number of cyclic sulphones has been studied, with a view to developing these reactions as possible synthetic processes.

Some substituted dihydronaphthothiophene sulphones were prepared and those containing a pent-4-ene sidechain successfully underwent intramolecular Diels-Alder cyclisations.

2-Phenylthietan was prepared by a new route and the preparation and pyrolysis of some 2-phenylthietan 1,1-dioxide derivatives was studied.

Some 2-(alkan-1-ol)-3,3-dimethylthietan sulphones were prepared and the dehydration of these, with a view to preparing alk-1-ene derivatives, was studied. Phosphorus oxychloride in pyridine was the most successful of those reagents tried. The alk-1-ene derivatives were shown to have unusual thermal behaviour; they ring-expanded to their respective sultines under flash vacuum thermolysis conditions.

The use of 3,3-dimethylthietan 1,1-dioxide as a starting material for a new route to chrysanthemates has been studied. Methyl-trans-chrysanthemate was eventually identified as one of the products after a 4-step synthesis from this sulphone.

A number of cyclic sulphides were prepared using phase transfer catalysis.