CHAPTER III

SIMMONS–SMITH REACTION ON α-OXOKETENE DITHIOACETALS: A NOVEL ROUTE TO 3-, 3,4-
SUBSTITUTED AND ANNELATED THIOPHENES*.

III.1 INTRODUCTION

The reaction of an olefin with organozinc reagent prepared from methylene iodide and zinc-copper couple to afford the corresponding cyclopropane is generally termed as Simmons–Smith reaction, which was discovered by these chemists in 1950\(^1,2\). The cyclopropane formation is stereospecific with regard to the stereochemistry of the olefin and the reaction is usually free from undesirable side reactions. The method is of particular use, since it can be adopted for large scale preparations. The structure of the reagent and the mechanism of methylene transfer is not yet known with certainty.

The reagent, presumably the iodomethylzinc iodide is usually termed as carbenoid, which has been suggested for the description of intermediates which exhibits reactions qualitatively similar to those of carbenes without necessarily being free divalent carbon species.

Alkenes substituted with usual functional groups at sites remote from the double bond generally undergo cyclopropanation without difficulty. Conjugated dienes react readily with the zinc reagent to form mono- and di-adducts stereospecifically, whose ratio can often be controlled. Substituents like halogens, alkoxy group, esters, primary and secondary amines, carbonyl, ketals and sulphones do not interfere in the cyclopropanation \(^2\). The zinc reagent behaves as a weak electrophile towards the double bond and the reactivity of the double bond increases with electron donating substituents, while electron withdrawing substituents deactivate the process. If the functional group can coordinate with the zinc reagent, methylene transfer in such cases may be accelerated even with electron withdrawing groups. Cyclopropanation occurs with high stereochemical control in allylic and homoallylic alcohols due to the coordination of the reagent with oxygen function \(^3\)\(^-\)\(^5\). \(\alpha,\beta\)-Unsaturated ketones are known to undergo cyclopropanation \(^6\) to form the cyclopropyl ketones, but the success of the reaction depends on the substrate structure. Some of the doubly \(\alpha,\beta\)-unsaturated ketones are known to give mono- and di-adducts depending on the amount of the reagent used \(^7\).

Since heteroatoms adjacent to the double bond do not interfere with cyclopropanation, Wenkert and coworkers have extensively studied the cyclopropanation of oxyolefins \(^8\). They have made use of Simmons-Smith
reaction as well as other methods of cyclopropanation to prepare the oxycyclopropane derivatives. These oxygenated cyclopropanes are shown to be useful intermediates in general organochemical reactions and complex natural product synthesis. Thus, enolethers 1 and 4 underwent facile cyclopropanation under Simmons-Smith reaction condition to give the cyclopropyl ethers 2 and 5, which on acid induced cleavage gave the α-methylated ketone 3 and the aldehyde 6 respectively. Similarly cyclopropane 8 with donor-acceptor functionalities was prepared by the copper assisted reaction of the diazoacetate with the cyclic enoether 7. The cyclopropane 8 in acidic condition was cleaved and cyclized to the fused lactone 9 (Scheme 1).

The ketene O,O-acetals of the general formula 10 are also known to give the stable cyclopropanone acetals 11 which with hydrochloric acid yielded 3-chloro-3-methyl-2-butanone 12 (R=CH₃). Similarly enamine 13 was converted to the 1-aminobicyclic alkane 14, and cleaved to 15. Reaction of phenylvinyl sulfone 16 with zinc reagent prepared from iodomethylbenzoate and zinc-copper couple to give cyclopropyl phenyl sulfone 17 represents an example of sulfur compound undergoing cyclopropanation under the described conditions (Scheme 2).

From these selected examples described above, despite the fact that Simmons-Smith reaction is not affected adversely by oxygen and nitrogen substituents and even by the presence of sulfones, there have been no example of olefins with divalent sulfur substituents such as vinyl sulfides, ketene S,S-acetals, β, β-bis(alkylthio)α, β-unsaturated enones studied under Simmons-Smith reaction condition. One reason for the lack of example in this area could be attributed to the facile
formation of sulfur ylids by electrophilic addition of carbenes and carbenoids to the divalent sulfur. The carbenoid nature of the Simmons-Smith reagent may lead to products other than cyclopropanation.

The author's search was therefore directed towards examples of carbene/carbenoid intermediates and their behaviour towards ketene S,S-acetals and some of the related compounds. Such examples would throw light on the behaviour of sulfur compounds towards Simmons-Smith reagent.

Although Simmons-Smith reaction has been successfully applied to vinyl sulfone 16 (Scheme 2), to make the corresponding cyclopropane 17, the clear absence of vinyl sulfides or ketene S,S-acetals under these reaction conditions certainly leads to the speculation of ambident behaviour of the reagent to these intermediates. However Seebach has successfully added a carbenoid generated from trisphenylmercaptomethyl-lithium 18 to ketene dithioacetal 19 to afford the corresponding cyclopropane 20\textsuperscript{13}, which is one of the rare examples of construction of cyclopropane ring on olefin containing a divalent sulfur, through carbenoid addition. Subsequently it was shown that addition of lithio derivative of phenyl trimethylsilylmethyl sulfide 21\textsuperscript{14} to ketene dithioacetals 22 yield the silylcyclopropane 23 (Scheme 3).

However, there have been larger number of examples where the divalent sulfur preferentially attacks the carbene to yield the sulfur ylid\textsuperscript{15} rather than the cyclopropane. In fact this is one of the general methods of preparation of sulfur ylids\textsuperscript{15}. Some examples involving participation of divalent sulfur with electrophilic carbenes to give the sulfur ylid and the products arising thereof have been illustrated
(C₆H₅S)₃Cl + CH₂=Y → X

X= Y= OMe, X= Y= SMe, X= Y= SC₆H₅

X= Y= -(CH₂)₃-S-, X= C₆H₅, Y= morpholino

C₆H₅S-TH₂ + Me₃Si-Cl → X

X= R₁=R₂=C₆H₅, R₁=R₂=SC₆H₅, R₁=R₂=SCH₃, R₁=SCH₃, R₂=SC₆H₅

Me₃Si-O⁻ + CH₂=Y → X

X= R₁=R₂=C₆H₅, R₁=R₂=SC₆H₅, R₁=R₂=SCH₃, R₁=SCH₃, R₂=SC₆H₅
Thus, generating dichlorocarbene in the presence of 2H-1-benzothio-
pyran 24 produced the insertion products 27 and 28 explicable on the 
basis of an ylid intermediate 26 through 25\textsuperscript{16,17}. Similarly the 
carbenoid derived from diazoacetate in thermal and photolytic condi-
tions preferentially attacked by sulfur rather than the double bond, 
in the allyl sulfide 29 to give the ylid intermediate 30 which on 
\[2,3\]sigmatropic rearrangement gave isomeric 31\textsuperscript{18,19} (Scheme 4). Another 
interesting example reported by Yoshimato and coworkers is the skeletal 
conversion of cephalosporin 32 to penicillin 34. This can be explained 
by the \[2,3\]-sigmatropic rearrangement of the intermediate cyclic 
allyl sulfonium \textit{ylid} 33 formed by the carbene insertion to divalent 
sulfur\textsuperscript{20} (Scheme 5).

Kametani and coworkers have exploited this unique property of sulfur 
as an efficient trap for carbenoid for the synthesis of some naturally 
occuring pyrrolizidine alkaloids. The key step involves the intra-
molecular carbenoid displacement (ICD) reaction of the diazo-sulfide 
to give the ylid 36, which on ring opening following by ring closure 
gives the product 38\textsuperscript{21} (Scheme 6).

It is apparent from the above examples, that sulfur in its divalent 
state react with carbene/carbenoids to form the corresponding sulfonium 
ylid. Dialkyl sulfide is known to be four times more reactive than an 
olefin towards carbene\textsuperscript{22}. Even dibenzothiophene in which the lone pair 
of sulfur is highly delocalized is an efficient trap for carbene\textsuperscript{22}.

There have also been rare examples, where the sulfonium ylid undergoing 
intramolecular reaction with electrophilic carbon centres within the
Scheme 5

Cu/Xylen/reflux

\[ \text{Ph} \text{N} \text{S} + \text{N}_2\text{CHCO}_2\text{C}_2\text{H}_5 \]

\[ \text{CO}_2\text{CH}_3 \]

\[ \text{Cu/} \text{Xylene/} \text{reflux} \]

\[ \text{N}_2\text{CHCO}_2\text{C}_2\text{H}_5 \]

\[ \text{CO}_2\text{CH}_3 \]

[2,3]

\[ \text{Ph} \text{N} \text{S} \]

\[ \text{CO}_2\text{CH}_3 \]

\[ \text{H}_3\text{CO}_2\text{C}_2\text{H}_5 \]

\[ \text{H}_3\text{CO}_2\text{C}_2\text{H}_5 \]

\[ \text{Ph} \text{N} \text{S} \]

\[ \text{CO}_2\text{CH}_3 \]

\[ \text{H}_3\text{CO}_2\text{C}_2\text{H}_5 \]

32

33

34
molecule. The first and only example reported in the literature is the intramolecular aldol type condensation of the ylid 40 generated from the corresponding dimethyl (o-aceto-p-tolyl) sulfonium methylsulfonate 39, to give the intermediate 41 which on demethylation give the benzothiophene 42 (Scheme 7). There are a few examples, in which the more stabilized dimethylsulfoxonium methylide undergoing condensation with carbonyl group. Thus dimethylsulfoxonium methylide gives the intermediate ylid 44 by Michael addition on the acetylenic ketone 43, followed by thermal dehydration to generate the S-methylthiabenzene S-oxide 45· S-oxide 46. Similarly 1,3-diketone 46 also underwent cyclocondensation with sulfoxonium methylide to give the annelated thiabenzene S-oxide 47 (Scheme 8).

The following conclusions may be made on the basis of the illustrations described above.

1. Simmons-Smith reaction is not affected by usual oxygen and nitrogen functionalities and also by sulfone whereas the examples of Simmons-Smith reaction with vinyl sulfides, ketene S,S-acetals and polarised ketene S,S-acetals have not been reported.

2. The electrophilic carbenes and carbenoids react with divalent sulfur compounds to give the corresponding sulfur ylid. Whereas vinyl ethers, ketene O,O-acetals and enamines react with carbene to give cyclopropanes.

3. Carbene addition to ketene S,S-acetals to afford cyclopropanes have been studied and examples are very few (Scheme 3).

4. There have been a few examples of sulfoxonium methylide undergoing aldol condensation with carbonyl group. However, no report of
sulfonium ylid undergoing aldol type condensation with carbonyl group is available, while they are known to give the epoxy compounds on reaction with carbonyl compounds.

In conclusion, it is of immense practical interest to see, how α-oxoketene S,S-acetal behave towards Simmons-Smith reagent, whether cyclopropanation on mercapto double bond or electrophilic attack on the thiomethyl sulfur to give the sulfur ylid and the products arising from it. In the examples given above, some of these questions related to the reaction of α-oxoketene dithioacetal towards Simmons-Smith reaction and other carbene/carbenoids, and possible intramolecular aldol type condensation of the sulfur ylids have been highlighted, so that the course of chemical events of the present investigation would be easily understood.

III.2 RESULTS AND DISCUSSION

This Chapter deals with the reaction of α-oxoketene dithioacetals under Simmons-Smith reaction condition, indeed leading to 2-methylthio-4-substituted and 3,4-disubstituted thiophenes. The formation of these thiophenes are rationalised on the basis of examples illustrated in the introduction. On the basis of structural characteristics of starting α-oxoketene dithioacetals and the corresponding distribution of substituents in the product thiophenes the presentation is divided into three parts.

III.2.1 SYNTHESIS OF 2-METHYLTHIO-4-SUBSTITUTED AND 2-METHYLTHIO-3,4-DISUBSTITUTED THIOPHENES

The selected α-oxoketene dithioacetals required for the present investigation were prepared according to the known procedure by reacting the respective active methylene ketones with two equivalent
of base and carbondisulfide followed by alkylation. Authenticity of these compounds were confirmed by comparison of their spectral and analytical data with those of reported values.

In a typical experiment, the ketene dithioacetal 48a was reacted with Simmons-Smith reagent prepared from methylene iodide and zinc-copper couple in Et₂O/THF mixture (experimental) afforded a pale yellow solid, m.p. 42°C which was characterised as 2-methylthio-4-phenylthiophene 49a in 61% yield. The structure of 49a was fully established by its analytical and spectral data. Thus, compound 49a was analysed for C₁₁H₁₀S₂ and exhibited molecular ion peak at m/z 206(100%). The infrared spectrum showed clear absence of a carbonyl group. In its ¹H n.m.r. the signal at 62.30 was assigned for thiomethyl protons. The phenyl and thiophene protons appeared as a multiplet between 6 7.10-7.59. The ¹³C n.m.r. spectrum is also in full agreement with the assigned structure (experimental). Further structural proof was achieved by its independent synthesis²⁹,³⁰ by the method report by Marino and Kostusyk*. Also careful desulphurisation of thiophene 49a gave the known thiophene 50a ³¹ (Scheme 9).

The high resolution (400 MHz) ¹H n.m.r. spectrum of thiophene 49b was found to be more useful for the assignment of substitution pattern in the thiophene ring. The signal due to C-3 and C-5 protons were found to be clearly separated from the phenyl protons. The signals at 62.30 and 2.46 were assigned to CH₃ and SCH₃ protons, while the doublet at 6 7.13 (J=8.5Hz, 2H) was assigned for phenyl protons. The signals due

* The i.r. and n.m.r. spectra of 49a were superimposable with the product prepared by Marino's method, while the melting point reported (92°C) was found to be incorrect. The thiophene 49d showed same melting point (102-103°C) as reported.
to H-3 and H-5 protons appeared at 67.27 (J=1.5 Hz) and 7.30 (J=1.5 Hz). The other phenyl protons appeared at 67.39 (J=8.5 Hz, 2H). The coupling value (J=1.5 Hz) evidently fits for the long range coupling between H-3 and H-5 signals. The possibility of getting the other regioisomeric thiophene will be discussed later.

The probable mechanism for the above transformation apparently involves the carbenoid methylene insertion to one of the sulfur atoms of the \( \alpha \)-oxoketene dithioacetal 48 to give the sulfonium ylid intermediate 52a which on intramolecular aldol type condensation assisted by coordination of zinc with carbonyl oxygen gives the S-methylthiophenium salt 52b. Subsequent demethylation of the intermediate 52b afforded the thiophene 49 (Scheme 10). The sequence seems to be valid in the light of examples given in the introduction.

The other speculative pathways the reaction can adopt is outlined in Scheme 11. Like 0,0-acetals if the \( \alpha \)-oxoketene dithioacetal 48 react with Simmons-Smith reagent it should in principle yield 2,2-bis(methylthio)-1-benzoyl cyclopropane 53 (R²=H). This intermediate is expected to undergo facile ring cleavage due to the presence of donor-acceptor functionalities in the vicinal carbon atoms. Thus the intermediate 53 can in principle give the furan 55 (path a), which was not observed in the reaction. Okazaki and coworkers have reported similar approach for the synthesis of furans from \( \alpha \)-oxoketene dithioacetal through an epoxyketene dithioacetal intermediate 35,36. The other possibility is the dethiomethylation of the intermediate 53 to give the \( \alpha \)-oxodithioester 56 (path b) which can give thiophene 57 isomeric with observed thiophene 49. This possibility is ruled out on the basis of \(^1\)H n.m.r. spectrum.
If the reaction follows path b (Scheme 11), \( \alpha \)-oxoketene dithioacetal 48b should give regioisomeric 2-methylthio-5-(4-methylphenyl)thiophene. The coupling constant for C-3 and C-4 protons in this thiophene is expected to be around 3.5–4.5 Hz \(^{37a}\), whereas the observed value is only 1.5 Hz. Thus, the possibility of the 5-regioisomer is ruled out. Therefore the structure of thiophenes 49 is conclusively established and mechanism proposed in Scheme 12 appropriately fits in.

The other \( \alpha \)-oxoketene dithioacetals 48c–k were also transformed to the corresponding thiophenes 49c–k in 54–67% overall yield (Scheme 9). The structure of all these thiophenes were fully established by their analytical and spectral data, described in the experimental section. Another interesting observation is that an isolated double bond in 48k is carried over to the 3-position in the product thiophene 49k without being participating in Simmons-Smith reaction.

Although thiophene ring is known to rupture by Raney Nickel \(^{38a}\), the thiophenes 49a–c were successfully dethiomethylated to the corresponding arylthiophenes 50a–c by using W-2 Raney Nickel in methanol at room temperature in 51–57% overall yield. Under similar reaction conditions thiophene 49j underwent reductive desulphurisation to give 2,3-diphenyl-butane 51 in 72% yield. The thiophene ring in 49j could not be retained even by W-1 Raney Nickel \(^{39}\). Similarly \( \alpha \)-oxoketene dithioacetals 58a and 58b derived from 2-acetylfuran and 2-acetylthiophene underwent thiophene formation to give 2-methylthio-4-(2-furyl) and 4-(2-thienyl) thiophenes 59a and 59b in 58 and 63% yields respectively (Scheme 12).

The structural assignment was fully established by analytical and spectral
The reaction was extended to $\alpha$-oxoketene dithioacetals prepared from aliphatic ketones. Thus, $\alpha$-oxoketene dithioacetals $60a-d$ smoothly reacted under Simmons-Smith reaction condition to yield the corresponding thiophenes $61a-d$ in 53-62% overall yield (Scheme 12). Compound $61a$ was isolated as a colourless liquid. In its $^1H$ n.m.r. spectrum the two thiophene protons (H-3 and H-5) appeared as a broad singlet at $\delta 6.80$. The H-5 thiophene protons in $61b$, $61c$ and $61d$ appeared as broad singlets at $\delta 6.80$, 6.81 and 6.82 respectively. Spectral and analytical data are given in the experimental.

III.2.2 SYNTHESIS OF 2-METHYLTHIO-3,4-ANNELATED THIOPHENES

In the previous section, the reactivity of $\alpha$-oxoketene dithioacetals derived from alkyl and aryl ketones towards Simmons-Smith reagent have been presented. In this section various cyclic $\alpha$-oxoketene dithioacetals have been investigated with a view of extending the present methodology for the synthesis of 3,4-annelated thiophenes. The literature methods available for the synthesis of 3,4-fused thiophenes are scanty and suffers from lack of generality $^{30,38b}$. Considering the fact that a number of cyclic ketones can be converted to the corresponding dithioacetals, the method should be promising for the synthesis of these class of thiophenes.

The representative cyclic $\alpha$-oxoketene dithioacetals $62a,b$, $64a,b$, $66$ and $68$ were prepared according to the reported method$^{28}$ and characterised by comparison of their physical and spectral data with those of reported values. Thus $62a$ derived from cyclohexanone was reacted with methylene
iodide and zinc-copper couple in identical condition yielded a colourless oily liquid, characterised as 2-methylthiocyclohexa[\(\text{g}\)]thiophene 63a (65%). In its \(^1H\) n.m.r. spectrum the characteristic H-5 signal of thiophene ring appeared as a singlet at \(56.76\) which supplements other proofs for structural assignment. Similarly 63b was obtained from 62b in identical conditions (Scheme 13).

The method was found to be equally efficient when extended to dithioacetals derived from benzocyclic ketones. Thus thiophenes 65a and 65b were formed in 57 and 60% yields respectively from the corresponding dithioacetals 64a and 64b (Scheme 13). The reaction was also extended to dithioacetals 66 and 68 prepared from benzothiepinone and benzoexepinone, and was readily converted to the thiophenes 67 and 69 in 61 and 62% yield (Scheme 14). Analytical and spectral data are given in the experimental. The method may also find use in introducing other hetero atoms in the main skeleton.

However, the method was found to be inefficient for thiophene annelation on five membered rings. Thus dithioacetals derived from cyclopentanone and indanone failed to give the annelated thiophenes, and no tractable product could be isolated from the reaction mixture.

III.2.3 SYNTHESIS OF 2-METHYLTIO-4-ENYL/CYCLOPROPYL/CYCLOPROPYLENYL-3-UNSUBSTITUTED/ALKYLTHIOPHENES

In the earlier sections the successful conversion of \(\kappa\)-oxoketene dithioacetals derived from various alkyl, aryl and cyclic ketones to the corresponding thiophenes are described. Further, it was considered of interest to modify the substrate structure by replacing the alkyl
Scheme 13

H

\[ \text{Zn-Cu/CH}_2\text{I}_2 \rightarrow \text{Et}_2\text{O/THF} \]

\[ \text{SMe} \]

\[ (\text{CH}_2)\text{n} \]

\[ \text{62, 63 a n=1 b n=2} \]

\[ \text{SMe} \]

\[ \text{H} \]

\[ \text{SMe} \]

\[ \text{Zn-Cu/CH}_2\text{I}_2 \rightarrow \text{Et}_2\text{O/THF} \]

\[ \text{SMe} \]

\[ (\text{CH}_2)\text{n} \]

\[ \text{64, 65 a n=1 b n=2} \]
Scheme 14

Zn-Cu/CH₂I₂ / Et₂O / THF

H₃C

67

H₃C

68

SMe

SMe

66

SMe

SMe

69
and aryl substituents by a styryl moiety. The importance of this substrate stems from the fact that \( \alpha,\beta \)-unsaturated ketones are known to undergo cyclopropanation under Simmons-Smith reaction, therefore the reaction can give an idea about the degree of selectivity of the reagent towards sulfide sulfur in presence of a double bond in the same molecule.

The cinnamoyl ketene dithioacetals \( 72a-g \) selected for the study were prepared by published methods by condensing suitable acylketene dithioacetals with benzaldehydes using two equivalents of sodium ethoxide in ethanol (see table). Detailed procedure is given in the experimental section.

The cinnamoyl ketene dithioacetal \( 72a \) was reacted with the zinc reagent prepared from methylene iodide and zinc-copper couple under the described conditions yielded a white crystalline solid m.p. 58-59°C which was characterised as 2-methylthio-4-styrylthiophene \( 73a \) formed in 58% yield. Analytical and spectral data are in complete agreement with the assigned structure and is given in the experimental section. The presence of an additional double bond did not interfere in the thiophene formation showing the regiospecific nature of carbenoid addition. Under identical conditions cinnamoylketene dithioacetals \( 72b-g \) gave the styrylthiophenes \( 73b-g \) in 59-68% overall yield (Scheme 15). Structure of all these compounds were confirmed by spectral and analytical data described in the experimental. Styrylthiophenes are of particular interest since they are known to be excellent dienes in cycloaddition reactions.

With the above results, the reaction was extended to 5-aryl-2,4-pentadienoyl ketene dithioacetals \( 72h-m \) prepared by condensation of acylketene
\[ \text{RCHO} + \text{H}_3\text{C} \rightarrow \text{H} \quad \text{NaOEt} \quad \text{EtOH} \quad \text{SMe} \quad \text{R~SMe} \quad \text{H} \quad \text{R}_1 \]

72

a \quad \text{R}=\text{C}_6\text{H}_5; \text{R}^1=\text{H}

b \quad \text{R}=4-\text{ClC}_6\text{H}_4; \text{R}^1=\text{H}

c \quad \text{R}=3,4\text{-methylenedioxy C}_6\text{H}_3; \text{R}^1=\text{H}

d \quad \text{R}=2-\text{ClC}_6\text{H}_4; \text{R}^1=\text{H}

e \quad \text{R}=\text{C}_6\text{H}_5; \text{R}^1=\text{CH}_3

f \quad \text{R}=4\text{-MeOC}_6\text{H}_4; \text{R}^1=\text{CH}_3

g \quad \text{R}=3,4\text{-methylenedioxy C}_6\text{H}_3; \text{R}^1=\text{CH}_3

h \quad \text{R}=\text{C}_6\text{H}_5\text{CH=CH}-; \text{R}^1=\text{H}

i \quad \text{R}=4\text{-MeOC}_6\text{H}_4\text{CH=CH}-; \text{R}^1=\text{H}

j \quad \text{R}=3,4\text{-methylenedioxy C}_6\text{H}_3\text{CH=CH}-; \text{R}^1=\text{H}

k \quad \text{R}=\text{C}_6\text{H}_5\text{CH=CH}-; \text{R}^1=\text{CH}_3

l \quad \text{R}=3,4\text{-methylenedioxy C}_6\text{H}_3\text{CH=CH}-; \text{R}^1=\text{CH}_3

m \quad \text{R}=4\text{-MeOC}_6\text{H}_4\text{CH=CH}-; \text{R}^1=\text{n-C}_4\text{H}_9

n \quad \text{R}=\text{C}_6\text{H}_5(\text{CH=CH})_2-; \text{R}^1=\text{H}

o \quad \text{R}=3,4\text{-methylenedioxy C}_6\text{H}_3(\text{CH=CH})_2-; \text{R}^1=\text{H}

p \quad \text{R}=3,4\text{-methylenedioxy C}_6\text{H}_3(\text{CH=CH})_2-; \text{R}^1=\text{CH}_3

q \quad \text{R}=4\text{-MeOC}_6\text{H}_4; \text{R}^1=\text{H}

Table
Scheme 15

Zn-Cu / CH₂I₂

Et₂O / THF

22, 73

72 a-g

73 a-g

<table>
<thead>
<tr>
<th>72 a-g</th>
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<tbody>
<tr>
<td>Ar = C₆H₅, R = H</td>
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<tr>
<td>Ar = 4-ClC₆H₄, R = H</td>
</tr>
<tr>
<td>Ar = 3,4-methylenedioxyC₆H₃, R = H</td>
</tr>
<tr>
<td>Ar = 4-MeOC₆H₄, R = CH₃</td>
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<tr>
<td>Ar = 3,4-methylenedioxyC₆H₃, R = CH₃</td>
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<td>Ar = C₆H₅, R = CH₃</td>
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<tr>
<td>Ar = 4-MeOC₆H₄, R = CH₃</td>
</tr>
</tbody>
</table>

73 a-g

| Ar = C₆H₅, R = H |
| Ar = 4-ClC₆H₄, R = H |
| Ar = 3,4-methylenedioxyC₆H₃, R = H |
| Ar = 4-MeOC₆H₄, R = CH₃ |
| Ar = 3,4-methylenedioxyC₆H₃, R = CH₃ |
| Ar = 4-ClC₆H₄, R = CH₃ |
| Ar = C₆H₅, R = CH₃ |
| Ar = 4-MeOC₆H₄, R = CH₃ |
dithioacetals with suitable cinnamaldehyde following the same procedure given in the experimental. Structure of all the known products were confirmed by comparison with that of reported data and the data for the unknown compound 72m is given in the experimental section.

These systems are of special interest, since they carry a diene moiety in conjugation with carbonyl group and should give product thiophenes with a diene skeleton retained in the 4-position. Thiophenes with 1,3-butenadienyl side chain in 2- and 3-position is known to give interesting results under photolysis, and no general route is available in the literature for the synthesis of these class of thiophenes.

Thus 4-aryl-2,4-pentadienoylketene dithioacetals 72h-m under described transformation yielded the 4-(4-aryl-1,3-butadienyl) thiophenes 73h-m in 60-67% overall yield (Scheme 16). Analytical and spectral evidence in support of the assigned structure is given in the experimental section.

The cinnamoylketene dithioacetal 75a and 5-aryl-2,4-pentadienoylketene dithioacetal 75b prepared by condensing the respective aldehyde with 1,1-bis(methylthio)2-methylpentane-3-one needs special comment as it can lead to methyl substitution at 3-position of thiophene ring and also in the side chain double bond. The dithioacetals 75a and 75b yielded the thiophene 76a and 76b in 61 and 58% yield (Scheme 17). $^1$H n.m.r. spectra of thiophene 75a and 75b showed broad singlets for side chain methyl groups at 5 2.21 and 2.10 due to allylic coupling. Other spectral and analytical values are given in the experimental. The thiophene 76a underwent complete reductive desulphurization by W-2 Raney Nickel in methanol at room temperature to give the saturated hydrocarbon 77 (Scheme 17).
Scheme 16

Ar

R

Zn-Cu / CH₂I₂

Et₂O / THF

Ar=C₆H₅, R=H

Ar=4-MeOC₆H₄, R=H

Ar=3.4-methylenedioxy C₆H₃, R=H

Ar=C₆H₅, R=CH₃

Ar=3.4-methylenedioxy C₆H₃, R=CH₃

Ar=4-MeOC₆H₄, R=n-C₄H₉
Scheme 17

75,76 \[ \text{Ar:3,4-dimethoxy C}_6\text{H}_3 \]

74 \[ \text{b Ar= } \text{C}_6\text{H}_5\text{CH=CH} \]

76 \[ \text{Zn-Cu / CH}_2\text{I}_2 \text{ Et}_2\text{O / THF} \]

77 \[ \text{Raney Ni / MeOH} \text{ Ar=3,4-dimethoxy C}_6\text{H}_3 \]

70 \[ \text{ArCHO} \]
Spectral and analytical data in support of the structure of compound 77 is given in experimental section.

In this stage of the study, it is almost convincingly proved that the method can be adapted for the synthesis of thiophenes with 4-polyenyl side chain, if the dithioacetal with suitable polyene side chain is available. This requirement is partially met in 7-aryl-2,4,6-hepta-trienoylketene dithioacetals 72n-p. These new compounds were synthesized by the careful condensation of the respective 5-aryl-2,4-pentadienals with acylketene dithioacetals by the method reported in the experimental section. The diene aldehydes are prepared by following the Vilsmeier-Haack route as reported by Krishna Rao and coworkers47. Dithioacetals 72n-p were obtained in 81-85% overall yield and showed satisfactory spectral and analytical data, described in the experimental section.

Thus, dithioacetals 72n-p were subjected to Simmons-Smith reaction following the general procedure, work-up and column chromatography on silica gel gave the expected 4-(6-aryl-1,3,5-hexatrienyl) thiophene 73n-p in 68-70% overall yield (Scheme 18). In the high resolution (400 MHz) $^1$H n.m.r. spectrum of 73n the signals due to thiophene ring protons were clearly separated and appeared as broad singlets at 7.09 (H-3) and 7.20(H-5), while part of the olefinic protons appeared as a multiplet. Other spectral and analytical evidence in support of the assigned structure is given in the experimental. Also thiophene 73o and 73p showed satisfactory spectral and analytical data (experimental).

The thiophenes 73n and 73p underwent complete reductive desulphurisation in Raney Nickel/methanol at room temperature to give the long chain
Scheme 18
hydrocarbon 78a and 78b in 70 and 71% yield. Spectral and analytical data are given in the experimental.

Finally, the substrates selected for the study were α-oxoketene dithioacetals with a preconstructed cyclopropane ring and cyclopropane ring with enyl and dienyl side chain adjacent to the carbonyl group. These intermediates are prepared in excellent yield by the method recently developed in this laboratory. Regiospecific cyclopropanation is achieved by the reaction of the respective enoylketene dithioacetals with dimethylsulfoxonium methyldide under phase transfer condition. Detailed procedure is given in the experimental section. All the cyclopropyl ketones 79a-e selected for the study were prepared by the above method from the corresponding enoylketene dithioacetals 72a,g,g,h and 72n in 82-93% overall yield (Scheme 19). Structural assignment is fully established on the basis of spectral and analytical data given in the experimental section.

Compound 79d and 79e claims special attention in terms of structural features. In compound 79d the double bond is no more in conjugation with the carbonyl group and can behave as an isolated double bond and in 79a an isolated diene fragment is present in similar status. These structural features makes them interesting substrates to study in Simmons-Smith reaction condition in view of understanding the degree of selectivity of the carbenoid addition.

In an analogous manner cyclopropyl ketene dithioacetals 79a-c were subjected to Simmons-Smith reaction, usual work up and column chromatography gave the cyclopropyl thiophenes 80a-c in 57-61% overall yield.
$^1$H n.m.r. spectra of 80a–c unambiguously showed the presence of cyclopropane ring. Similarly 79d and 79c were also transformed to the corresponding cyclopropyl thiophenes 80d and 80e in 54 and 56% yield (Scheme 20). Although yields are comparatively low, the double bonds attached to the cyclopropane ring remained unaffected which is evident from their $^1$H n.m.r. spectra. Spectral and analytical data in support of the assigned structure is given in the experimental section.

III.3 CONCLUSION

It is the experience of the author that the methodology developed for the thiophene synthesis described above via oxoketene dithioacetal is of considerable synthetic value. Evidently this is mainly due to the fact that a wide variety of $\alpha$-oxoketene dithioacetals can be prepared from various class of active methylene ketones. Also another class of dithioacetals can be prepared by condensing the acylketene dithioacetals with various aldehydes. Another important factor is that the reaction can tolerate any structural variation on the $\alpha$-oxoketene dithioacetal moiety.

By suitable manipulation of the substrate structure, thiophenes substituted at 3-position or 3,4-position can be obtained besides 3,4-annelated ones. Despite abundant literature on thiophene synthesis most of the methods are leading to 2- or 2,5-disubstituted thiophenes. Only very few methods are reported in the literature for the synthesis of 3- or 3,4-disubstituted thiophenes $^{30,37b,38b}$.

An interesting and qualitatively similar approach reported in the literature is due to Marino and Kostusyk$^{30}$ using the same intermediates.
(Scheme 21). The reaction involves selective deprotonation of the thio­methyl group cis to carbonyl group to give the stabilised anion 81, which undergoes cyclisation to give thiophenes 49. However, the method suffers from many serious drawbacks such as (1) The reported yields are very poor (22-42%) and only in one case the yield recorded is 55%. (2) The method fails for all acylketene dithioacetals i.e. it cannot be used for the synthesis of any 4-alkyl or 3,4-dialkyl thiophenes. This is due to the preferential formation of enolate ion rather than S-methyl deprotonation. Structural limitations for 3,4-annelated thiophenes are also evident from the representative cyclic α-oxoketene dithioacetal 84 selected in their study. The method cannot be used for the synthesis of 4-enylthiophene due to vinylic deprotonation. (3) The substituent at α-position cannot be a methyl group due to allylic anion formation, although higher alkyl chains are tolerated. Thus, a methyl group cannot be introduced in the 3-position of thiophene ring.

The methodology developed is of considerable synthetic importance and provides a simple two step route to not easily accessible 3- or 3,4-disubstituted thiophenes from a wide variety of commercially available active methyl and methylene ketones. Again the method distinguishes itself from other thiophene synthesis since it involves a facile intramolecular aldol type condensation of the sulphonium ylid intermediate resulting in ring closure. Although carbenes are known to add to sulfur to yield sulfur ylids, this represents the first report on their formation under Simmons-Smith reaction condition.
III.4 EXPERIMENTAL

Melting points were determined on a Thomas Hoover capillary melting point apparatus and are uncorrected. I.r. spectra of crystalline compounds were determined for KBr discs and those of other compounds for thin films on a Perkin-Elmer 297 spectrophotometer. $^1$H n.m.r. spectra were determined on a Varian EM-390 (90 MHz) spectrometer in deuteriochloroform with tetramethylsilane as internal standard unless otherwise indicated. Chemical shifts are expressed as $\delta$(ppm) downfield from TMS. $^{13}$C n.m.r. spectra were recorded on a Brucker WM-400 spectrometer. Mass spectra were obtained using a Jeol JMS D-300 spectrometer. Microanalysis were done at Central Drug Research Institute, Lucknow.

Starting Materials

Commercially available ketones were purchased (Aldrich) and were used as supplied. Other ketones were prepared by reported procedure. All liquid aldehydes were distilled free of acid before use. Some of the substituted cinnamaldehydes and higher homologues were prepared according to the reported procedure. Zinc-copper couple was purchased (Ventron) and was dried at 120°C for 24 hr. prior to use. Methylene iodide was distilled before use. Diethyl ether and tetrahydrofuran were dried over sodium wire and distilled prior to use. All $\alpha$-oxoketene dithioacetals $48a$-i, $58a$-b, $60a$-d, $62a$-h, $64a$-b, $66$ and $68$ were prepared according to the general procedure described in Chapter II. The cinnamoyl ketene dithioacetals $72a$-g, $72a$, $75a$, 5-aryl-2,4-pentadienoyl $72h$-m, $75b$ and 7-aryl-2,4,6-heptatrienoyl $72n$-p ketene dithioacetals were prepared as given below.
Condensation of α-acylketene dithioacetals with aldehydes: General procedure for the preparation of compounds (72a-g, 75a and 75b):

To a cooled and stirred solution of sodium ethoxide in ethanol, prepared by dissolving sodium (0.06 mol) in ethanol (30 ml), a solution of the α-acylketene dithioacetal (0.03 mol) and the aldehyde (0.03 mol) in minimum ethanol was added dropwise over a period of 5 minutes. The reaction mixture was brought to room temperature over a period of 20 minutes and further stirred at room temperature for 4-5 hrs. The mixture was diluted with cold water (100 ml) and the solid separated out was filtered, washed with water (4x100 ml) and dried. The compounds 72a-l, 75a and 75b were previously reported and the physical and spectral data were found to be in conformity with that of reported values. The data of unknown compounds 72m and 72n-p are given below.

1,1-Bis(methylthio)-2-(n-butyl)-7-(4-methoxyphenyl)-1,4,6-heptatriene-3-one (72m) was isolated as yellow crystalline solid (methanol), yield 78%; m.p. 60-61°C; $\nu_{\text{max}}$ 1600, 1506 cm$^{-1}$; $\delta_H$ 0.89(3H,distorted t,CH$_3$), 1.20(4H,m,CH$_2$), 2.22(3H,s,SCH$_3$), 2.43(3H,s,SCH$_3$), 2.44-2.73(2H,m,CH$_2$), 3.78(3H,s,OCH$_3$), 6.26(1H,d,J=16Hz,H-4), 6.69-6.93(5H,m,arom and olefinic), 7.34(2H,d,J=8.5Hz,A$_2$B$_2$,arom). (Found: C,66.18; H,7.30. C$_{20}$H$_{26}$O$_2$S$_2$ requires: C,66.26; H,7.23%); m/z 362(2%,M$^+$), 347(100).

1,1-Bis(methylthio)-9-phenyl-1,4,6,8-nonatetraene-3-one (72n) was isolated as brown solid (methanol), yield 82%; m.p. 142-143°C; $\nu_{\text{max}}$ 1619, 1550, 1458 cm$^{-1}$; $\delta_H$ 2.48(6H,s,SCH$_3$), 6.10(1H,s,H-2), 6.27(1H,d,J=16Hz, H-4), 6.39-7.90(5H,m,olefinic), 7.16-7.53(5H,m,arom). (Found: C,67.26; H,6.11. C$_{17}$H$_{18}$O$_2$S$_2$ requires: C,67.51; H,6.00%).
1,1-Bis(methylthio)-9-(3,4-methylenedioxyphenyl)-1,4,6,8-nonatetraene-3-one (72o) was isolated as brown solid (methanol), yield 85%; m.p. 149-150°C; \( \nu_{max} \) 1610, 1594, 1512 cm\(^{-1} \); \( \delta_H \) 2.49(6H,s,SCH\(_3\)), 5.97(2H,s,CH\(_2\)); 6.14(1H,s,H-2), 6.23(1H,d,J=16Hz,H-4), 6.60-7.03(6H,m,arom and olefinic), 7.15-7.49(2H,m,arom). (Found: C,62.38; H,5.19. \( C_{18}H_{18}O_3S_2 \) requires: C,62.40; H,5.24%).

1,1-Bis(methylthio)-2-methyl-9-(3,4-methylenedioxyphenyl-1,4,6,8-nonatetraene-3-one (72p) was isolated as brown solid (methanol), yield 81%; m.p. 110-111°C; \( \nu_{max} \) 1638, 1583, 1560 cm\(^{-1} \); \( \delta_H \) 2.13(3H,s,SCH\(_3\)), 2.24(3H,s,SCH\(_3\)), 2.36(3H,s,CH\(_3\)), 5.97(2H,s,CH\(_2\)), 6.29(1H,d,J=16Hz, H-4), 6.49-7.30(8H,m,arom and olefinic). (Found: C,63.46; H,5.71. \( C_{19}H_{20}O_3S_2 \) requires: C,63.30; H,5.59%).

Cyclopropanation of \( \alpha \)-enoyldithioacetals using DMSY: General procedure for the preparation of cyclopropylketene dithioacetals (79a-e):

A solution of 50% aqueous NaOH solution (50 ml) was introduced beneath a solution of the substrate (0.01 mol) and the phase transfer catalyst (TBAI)(0.013 mol) in dichloromethane (50 ml). Trimethylsulfoxonium iodide (0.011 mol) was added and the mixture is maintained at 45-50°C with vigorous stirring for 16-24 hr. (monitored by t.l.c.). The layers were separated and the organic layer was evaporated. The residue was diluted with EtOAc and the precipitated catalyst was removed by filtration. The ethyl acetate solution was evaporated and chromatographed over silica gel column using 5% EtOAc-hexane as eluent.

3,3-Bis(methylthio)-1-(2-phenylcyclopropyl)-2-propen-1-one (79a) was isolated as pale yellow solid (CH\(_2\)Cl\(_2\)-hexane), yield 90%; m.p. 104°C;
$\nu_{\text{max}}$ 1620, 1479 cm$^{-1}$; $\delta_{\text{H}}$ 1.21-1.45 (1H, m, CH$_2$ cyclopropyl), 1.61-1.86 (1H, m, CH$_2$ cyclopropyl), 1.99-2.23 (1H, m, CH cyclopropyl), 2.43 (3H, s, CH$_3$), 2.50 (3H, s, CH$_3$), 2.36-2.66 (1H, m, CH cyclopropyl, merged with CH$_3$), 6.16 (1H, s, vinylic), 7.00-7.33 (5H, m, arom). (Found: C, 63.49; H, 6.02. C$_{14}$H$_{16}$O$_2$S$_2$ requires: C, 63.60; H, 6.10%); m/z 264 (10%, M$^+$), 249 (100).

3,3-Bis(methylthio)-1-[2-(4-methoxyphenyl)cyclopropyl]-2-propen-1-one (79b) was isolated as pale yellow solid (CH$_2$Cl$_2$-hexane), yield 92%; m.p. 96-97°C; $\nu_{\text{max}}$ 1621, 1492 cm$^{-1}$; $\delta_{\text{H}}$ 1.14-1.37 (1H, m, CH$_2$ cyclopropyl), 1.52-1.80 (1H, m, CH$_2$ cyclopropyl), 1.79-2.04 (1H, m, CH cyclopropyl), 2.41 (3H, s, SCH$_3$), 2.43 (3H, s, SCH$_3$), 2.34-2.58 (1H, m, CH cyclopropyl, merged with SCH$_3$), 3.75 (3H, s, OCH$_3$), 6.16 (1H, s, olefinic), 6.76 (2H, d, J=9 Hz, ArH), 7.00 (2H, d, J=9 Hz, ArH). (Found: C, 65.02; H, 5.76. C$_{15}$H$_{18}$O$_2$S$_2$ requires: C, 65.18; H, 5.84%); m/z 294 (24%, M$^+$), 279 (43).

3,3-Bis(methylthio)-2-methyl-1-[2-(3,4-methylenedioxyphenyl)cyclopropyl]-2-propen-1-one (79c) was isolated as viscous liquid, yield 91%; $\nu_{\text{max}}$ 1568, 1490, 1432 cm$^{-1}$; $\delta_{\text{H}}$ 1.16-1.39 (1H, m, CH$_2$ cyclopropyl), 1.50-1.71 (1H, m, CH$_2$ cyclopropyl), 2.06 (3H, s, SCH$_3$), 2.12 (3H, s, SCH$_3$), 2.28 (3H, s, CH$_3$), 1.99-2.59 (2H, m, CH cyclopropyl, merged with SCH$_3$ and CH$_3$), 5.83 (2H, s, CH$_2$), 6.50-6.66 (3H, m, arom). (Found: C, 59.73; H, 5.68. C$_{16}$H$_{18}$O$_3$S$_2$ requires: C, 59.60; H, 5.63%); m/z 322 (12%, M$^+$), 307 (77), 276 (86).

3,3-Bis(methylthio)-1-(2-styrylcyclopropyl)-2-propen-1-one (79d) was isolated as pale yellow solid (CH$_2$Cl$_2$-hexane), yield 89%; m.p. 116-117°C; $\nu_{\text{max}}$ 1629, 1496 cm$^{-1}$; $\delta_{\text{H}}$ 0.89-1.20 (1H, m, CH$_2$ cyclopropyl), 1.48-1.73 (1H, m, CH$_2$ cyclopropyl), 1.88-2.44 (2H, m, CH cyclopropyl), 5.77 (1H, dd,
J=16 and 8Hz, CH=CHAr), 6.30(1H, d, J=16Hz, CH=CHArH), 7.28(5H, m, arom).
(Found: C, 65.99; H, 6.18. C_{16}H_{18}OS_{2} requires: C, 66.17; H, 6.25%; m/z 290(8%, M^+), 275(36).

3,3-Bis(methylthio)-1-[2-(4-phenyl-1,3,-butadienyl)cyclopropyl]-2-propen-1-one (79e) was isolated as pale yellow solid (CH$_2$Cl$_2$-hexane), yield 86%; m.p. 122-123°C; $\nu$ max 1626, 1471 cm$^{-1}$; $\delta$$_H$ 0.76-1.32(2H, m, CH$_2$ cyclopropyl), 1.49-1.72(1H, m, CH cyclopropyl), 1.86-2.18(1H, m, CH cyclopropyl), 2.42(6H, s, SCH$_3$), 5.37(1H, dd, J=16 and 8Hz, CH=CHAr), 6.13(1H, s, H-2), 6.21-6.63(3H, m, olefinic), 7.12-7.42(5H, m, arom).
(Found: C, 68.22; H, 6.41. C$_{18}$H$_{20}$OS$_2$ requires: C, 68.31; H, 6.37%; m/z 316(2%, M$^+$), 301(3).

General procedure for Simmons-Smith reaction: synthesis of thiophenes:
To a well stirred suspension of zinc-copper couple (4.0g) in dry ether (25 ml), under nitrogen atmosphere, a small crystal of iodine and CH$_2$I$_2$ (6.70g, 25 mmol) were added and the reaction mixture was refluxed for 45 minutes. A solution of the $\alpha$-oxoketene dithioacetal (10 mmol) in dry THF (15 ml) was added and the reaction mixture was refluxed with stirring for 5-8 hr. (monitored by t.l.c.). The solvent was removed under reduced pressure and the residue was diluted with chloroform (150 ml) and water (200 ml). The reaction mixture was filtered and the residue was washed with chloroform. The chloroform layer was separated and washed with saturated NH$_4$Cl solution, water, dried (Na$_2$SO$_4$) and concentrated to give the crude thiophene which was purified by column chromatography over silica gel using hexane as eluent.
2-Methylthio-4-phenylthiophene (49a) was isolated as light yellow crystals (hexane), yield 61%; m.p. 42°C; $\nu_{\text{max}}$ 1597, 1482, 1443, 1300 cm$^{-1}$; $\delta_H$ 2.43 (3H, s, SCH$_3$), 7.10-7.59 (7H, m, ArH+H-3 and H-5); $\delta_C$ 21.32 (SCH$_3$), 122.56 (C-5), 130.02 (C-3), 125.64, 126.64, 129.00 (C-H arom), 135.35 (C-1'), 138.28 (C-2), 144.42 (C-4). (Found: C, 64.32; H, 4.51. C$_{11}$H$_{10}$S$_2$ requires: C, 64.03; H, 4.88%; m/z 206 (100%, M$^+$), 191 (32), 147 (23).

2-Methylthio-4-(4-methylphenyl)thiophene (49b) was isolated as light yellow crystals (hexane), yield 64%; m.p. 60-61°C; $\nu_{\text{max}}$ 1499, 1413, 1305 cm$^{-1}$; $\delta_H$ (400 MHz) 2.30 (3H, s, SCH$_3$), 2.46 (3H, s, CH$_3$), 7.13 (2H, d, J=8.5Hz, ArH), 7.27 (1H, d, J=1.5Hz, H-3), 7.30 (1H, d, J=1.5Hz, H-5), 7.39 (2H, d, J=8.5Hz, ArH); $\delta_C$ 21.49 (SCH$_3$), 21.95 (CH$_3$), 122.10 (C-5), 130.26 (C-3), 126.41, 129.76 (C-H, ArH), 132.76, 136.86 (C-1' and C-4' of aryl), 138.14 (C-2), 142.58 (C-4). (Found: C, 65.20; H, 5.41. C$_{12}$H$_{12}$S$_2$ requires: C, 65.41; H, 5.49%; m/z 220 (100%, M$^+$), 205 (27), 161 (21).

2-Methylthio-4-(4-chlorophenyl)thiophene (49c) was isolated as light yellow crystals (hexane), yield 65%; m.p. 64°C; $\nu_{\text{max}}$ 1596, 1485, 1356 cm$^{-1}$; $\delta_H$ 2.44 (3H, s, SCH$_3$), 7.13-7.25 (2H, m, thiophene H), 7.26-7.45 (4H, m, arom); $\delta_C$ 21.88 (SCH$_3$), 122.57 (C-5), 129.51 (C-3), 127.36, 128.29 (CH arom), 133.01, 133.84 (C-1' and C-4' of aryl), 138.63, 141.20 (C-2 and C-4 of thiophene). (Found: C, 54.76; H, 3.80. C$_{11}$H$_9$ClS$_2$ requires: C, 54.90; H, 3.76%; m/z 242 and 240 (45, 100%, M$^+$).

2-Methylthio-4-(4-methoxyphenyl)thiophene (49d) was isolated as light yellow crystals (hexane), yield 62%; m.p. 102-103°C; $\nu_{\text{max}}$ 1601, 1529, 1498, 1410 cm$^{-1}$; $\delta_H$ (400 MHz) 2.51 (3H, s, SCH$_3$), 3.77 (3H, s, OCH$_3$), 6.79 (2H, d, J=8.5Hz, arom), 7.15 (1H, d, J=1.5Hz, H-3), 7.21 (1H, d, J=1.5Hz), 7.38 (2H,
2-Methylthio-4(2-naphthyl)thiophene (49e) was isolated as colourless crystals (hexane), yield 67%; m.p. 70-71°C; $\nu_{\text{max}}$ 1591, 1490, 1410 cm$^{-1}$; $\delta_{H}$ 2.43(3H, s, $\text{SCH}_3$), 7.29-7.89(9H, m, arom). (Found: C, 70.12; H, 5.38. C$_{15}$H$_{12}$S$_2$ requires: C, 70.27; H, 5.49%); m/z 256(100%, M$^+$), 241(28), 197(23).

3-Methyl-2-methylthio-4-phenylthiophene (49f) was isolated as light yellow liquid, yield 59%; $\nu_{\text{max}}$ 1599, 1576, 1484 cm$^{-1}$; $\delta_{H}$ 2.20(3H, s, $\text{SCH}_3$), 2.31(3H, s, $\text{CH}_3$), 7.05(1H, s, thiophene H), 7.26(5H, s, arom). (Found: C, 65.22; H, 5.38. C$_{12}$H$_{12}$S$_2$ requires: C, 65.41; H, 5.49%); m/z 220(100%, M$^+$), 205(35).

3-Ethyl-2-methylthio-4-phenylthiophene (49g) was isolated as light yellow liquid, yield 58%; $\nu_{\text{max}}$ 1598, 1574, 1482, 1440 cm$^{-1}$; $\delta_{H}$ 0.97 (3H, t, $J=7$ Hz, $\text{CH}_2\text{CH}_3$), 2.41(3H, s, $\text{SCH}_3$), 2.66(2H, q, $J=7$ Hz, $\text{CH}_2\text{CH}_3$), 7.09 (1H, s, thiophene H), 7.31(5H, s, arom). (Found: C, 66.49; H, 5.98. C$_{13}$H$_{14}$S$_2$ requires: C, 66.62; H, 6.02%); m/z 234(21%, M$^+$).

2-Methylthio-4-phenyl-3-(n-propyl)thiophene (49h) was isolated as light yellow liquid, yield 59%; $\nu_{\text{max}}$ 1595, 1573, 1520, 1487, 1440, 1360 cm$^{-1}$; $\delta_{H}$ 0.79(3H, t, $J=7$ Hz, $\text{CH}_2\text{CH}_2\text{CH}_3$), 1.30(2H, sext, $J=7.0$Hz, $\text{CH}_2\text{CH}_2\text{CH}_3$), 2.42(3H, s, $\text{SCH}_3$), 2.66(2H, t, $J=7.0$Hz, $\text{CH}_2\text{CH}_2\text{CH}_3$), 7.09(1H, s, thiophene H), 7.32(5H, s, arom). (Found: C, 67.83; H, 6.72. C$_{14}$H$_{16}$S$_2$ requires: C, 67.69; H, 6.49%); m/z 248(100%, M$^+$), 219(75), 172(49).

3-Benzyl-4-(4-chlorophenyl)-2-methylthiothiophene (49i) was isolated as viscous brown liquid, yield 58%; $\nu_{\text{max}}$ 1591, 1510, 1477, 1419 cm$^{-1}$;
3,4-Diphenyl-2-methylthiothiophene (49j) was isolated as colourless crystals (hexane), yield 54%; m.p. 99-100°C; $\nu_{\text{max}}$ 1598, 1479, 1435, 1428 cm$^{-1}$; $\delta_H$ 2.34 (3H, s, SCH$_3$), 6.97-7.40 (11H, m, ArH+thiophene H). (Found: C, 72.19; H, 4.92. C$_{17}$H$_{14}$S$_2$ requires: C, 72.30; H, 5.00%); m/z 282 (100%, M$^+$), 267 (29), 234 (52).

3-Allyl-2-methylthio-4-phenylthiophene (49k) was isolated as light yellow liquid, yield 60%; $\nu_{\text{max}}$ 1599, 1490, 1443, 1425 cm$^{-1}$; $\delta_H$ 2.37 (3H, s, SCH$_3$), 3.39 (2H, d, J=4.5Hz, CH$_2$-CH=CH$_2$), 4.84-5.07 (2H, m, CH$_2$-CH=CH$_2$), 5.56-5.97 (1H, m, CH$_2$-CH=CH$_2$), 7.12 (1H, s, thiophene H), 7.31 (5H, s, arom). (Found: C, 68.61; H, 6.01. C$_{14}$H$_{14}$S$_2$ requires: C, 68.25; H, 5.72%); m/z 246 (100%, M$^+$), 231 (86).

4-(2-furyl)-2-methylthiothiophene (59a) was isolated as colourless liquid turning dark on keeping, yield 58%; $\nu_{\text{max}}$ 1600, 1520, 1474, 1418 cm$^{-1}$; $\delta_H$ 2.46 (3H, s, SCH$_3$), 6.33 (2H, brs, H-3' and H-5' furyl), 7.19 (1H, brs, H-4' furyl), 7.36 (2H, brs, H-3 and H-5, thiophene). (Found: C, 54.82; H, 4.42. C$_9$H$_8$O$_2$S$_2$ requires: C, 55.07; H, 4.10%); m/z 196 (100%, M$^+$).

2-Methylthio-4-(2-thienyl)thiophene (59b) was isolated as light yellow liquid, yield 63%; $\nu_{\text{max}}$ 1498, 1427, 1410 cm$^{-1}$; $\delta_H$ 2.47 (3H, s, SCH$_3$), 6.87-7.28 (5H, m, thiophene H). (Found: C, 51.27; H, 4.02. C$_9$H$_8$S$_3$ requires: C, 50.90; H, 3.80%); m/z 212 (100%, M$^+$), 197 (45), 153 (58).

4-Methyl-2-methylthiothiophene (61a) was isolated as colourless volatile liquid, yield 53%; $\nu_{\text{max}}$ 1593, 1510, 1473, 1410 cm$^{-1}$; $\delta_H$ 2.20 (3H, brs, CH$_3$),
2.41(3H,s,SCH₃), 6.80(2H,s,H-3 and H-5). (Found: C,50.21; H,5.83. \( \text{C}_6\text{H}_8\text{S}_2 \) requires: C,49.96; H,5.59%); m/z 144(100%,M⁺).

3,4-Dimethyl-2-methylthiothiophene (6lb) was isolated as light yellow liquid, yield 56%; \( \nu_{\text{max}} \) 1430, 1380, 1363 cm⁻¹; \( \delta_H \) 2.10(3H,s,3-CH₃), 2.13(3H,s,4-CH₃), 2.29(3H,s,SCH₃), 6.80(1H,s,thiophene H). (Found: C,53.39; H,6.58. \( \text{C}_7\text{H}_{10}\text{S}_2 \) requires: C,53.11; H,6.37%); m/z 158(100%,M⁺).

4-Ethyl-3-methyl-2-methylthiothiophene (6lc) was isolated as light yellow liquid, yield 58%; \( \nu_{\text{max}} \) 1599, 1458, 1428, 1376 cm⁻¹; \( \delta_H \) 1.19 (3H,t,J=7.5Hz,CH₂CH₃), 2.16(3H,s,CH₃), 2.29(3H,s,SCH₃), 2.48(2H,q, CH₂CH₃), 6.81(1H,s,thiophene H). (Found: C,55.82; H,7.12. \( \text{C}_8\text{H}_{12}\text{S}_2 \) requires: C,55.76; H,7.02%); m/z 172(15%,M⁺).

3-(n-Butyl)-4-methyl-2-methylthiothiophene (6ld) was isolated as colourless liquid, yield 62%; \( \nu_{\text{max}} \) 1440, 1379, 1309, 1179 cm⁻¹; \( \delta_H \) 0.95(3H,distorted t(CH₂)₃CH₃), 1.23-1.54(4H,m,CH₂(CH₂)₂CH₃), 2.17(3H,s,CH₃), 2.36(3H,s,SCH₃), 2.61(2H,t,CH₂(CH₂)₂CH₃), 6.82(1H,s,H-5). (Found: C,60.24; H,8.33. \( \text{C}_{10}\text{H}_{16}\text{S}_2 \) requires: C,59.95; H,8.05%); m/z 200(64%,M⁺), 157(100).

2-Methylthiocyclohexa[c]thiophene (63a) was isolated as colourless liquid, yield 65%; \( \nu_{\text{max}} \) 1543, 1437, 1388 cm⁻¹; \( \delta_H \) 1.55-1.84(4H,m, CH₂), 2.34(3H,s,SCH₃), 2.60-2.82(4H,m,CH₂), 6.76(1H,s,thiophene H). (Found: C,58.90; H,6.83. \( \text{C}_9\text{H}_{12}\text{S}_2 \) requires: C,58.65; H,6.57%); m/z 184(100%,M⁺), 169(42).

2-Methylthiocyclohepta[c]thiophene (63b) was isolated as colourless liquid, yield 62%; \( \nu_{\text{max}} \) 1442, 1428, 1382, 1309 cm⁻¹; \( \delta_H \) 1.43-1.90 (6H,m,CH₂), 2.30(3H,s,SCH₃), 2.57-2.89(4H,m,CH₂), 6.73(1H,s,thiophene H).
2-Methylthio-3,4-dihyronaphtho[2,1-c]thiophene (63c) was isolated as viscous liquid, yield 57%; $\nu_{\text{max}}$ 1599, 1479, 1454, 1420 cm$^{-1}$; $\delta_H$ 2.32 (3H, s, SCH$_3$), 2.79 (4H, s, CH$_2$), 6.93-7.18 (3H, m, arom), 7.28 (1H, s, thiophene H), 7.32-7.50 (1H, m, arom). (Found: C, 66.83; H, 5.51. C$_{13}$H$_{14}$S$_2$ requires: C, 67.19; H, 5.21%); m/z 232 (100%, M$^+$), 217 (22).

2-Methylthio-4,5-dihydro-3H-benzocyclohepta[2,1-c]thiophene (65b) was isolated as viscous liquid, yield 60%; $\nu_{\text{max}}$ 1524, 1476, 1439, 1360 cm$^{-1}$; $\delta_H$ 1.83-2.24 (2H, quint, CH$_2$), 2.31 (3H, s, SCH$_3$), 2.38-2.71 (4H, m, CH$_2$), 7.00-7.24 (5H, m, arom and thiophene H). (Found: C, 68.52; H, 5.91. C$_{14}$H$_{14}$S$_2$ requires: C, 68.25; H, 5.73%); m/z 246 (100%, M$^+$), 231 (11).

2-Methylthio-3,4-dihydrobenzoxepino[2,1-c]thiophene (66) was isolated as viscous liquid, yield 61%; $\nu_{\text{max}}$ 1596, 1563, 1479, 1441 cm$^{-1}$; $\delta_H$ 2.27 (3H, s, SCH$_3$), 2.89 (2H, t, CH$_2$), 4.24 (2H, t, CH$_2$), 6.78-7.18 (3H, m, arom), 7.20 (1H, s, thiophene H), 7.25-7.41 (1H, m, arom). (Found: C, 62.62; H, 5.13. C$_{13}$H$_{12}$O$_2$S$_2$ requires: C, 62.87; H, 4.87%); m/z 248 (100%, M$^+$), 233 (44).

8-Methyl-2-methylthio-3,4-dihydrobenzothiepino[2,1-c]thiophene (69) was isolated as viscous brown semisolid, yield 62%; $\nu_{\text{max}}$ 1595, 1532, 1480, 1421 cm$^{-1}$; $\delta_H$ 2.32 (3H, s, CH$_3$), 2.38 (3H, s, SCH$_3$), 2.91-3.12 (2H, m, CH$_2$), 3.21-3.39 (2H, m, CH$_2$), 7.20-7.33 (3H, m, arom and thiophene H), 7.53 (1H, brs, arom). (Found: C, 60.21; H, 5.18. C$_{14}$H$_{14}$S$_3$ requires: C, 60.39; H, 5.07%); m/z 278 (100%, M$^+$), 263 (31).
2-Methylthio-4-styrylthiophene (73a) was isolated as light yellow crystalline solid (hexane), yield 58%; m.p. 58-59°C; $\nu_{\text{max}}$ 1600, 1580, 1498, 1453, 1425 cm$^{-1}$; $\delta_{\text{H}}$ 2.48(3H, s, SCH$_3$), 6.88(2H, s, olefinic), 7.01-7.48(7H, m, ArH+thiophene H). (Found: C, 67.28; H, 5.33. C$_{13}$H$_{12}$S$_2$ requires: C, 67.19; H, 5.21%); m/z 232(86%, M$^+$), 184(100).

2-Methylthio-4-(4-chlorostyryl)thiophene (73b) was isolated as colourless crystalline solid (hexane), yield 68%; m.p. 79-80°C; $\nu_{\text{max}}$ 1585, 1481, 1403, 1391 cm$^{-1}$; $\delta_{\text{H}}$ 2.48(3H, s, SCH$_3$); 6.75-7.33(8H, m, arom+olefinic+thiophene H). (Found: C, 58.58; H, 4.01. C$_{13}$H$_{11}$ClS$_2$ requires: C, 58.52; H, 4.16%); m/z 268 and 266(44, 100%, M$^+$), 184(58).

2-Methylthio-4-(3,4-methylenedioxy)styryl)thiophene (73c) was isolated as colourless crystalline solid (hexane), yield 63%; m.p. 65-66°C; $\nu_{\text{max}}$ 1598, 1510, 1495, 1479, 1440 cm$^{-1}$; $\delta_{\text{H}}$ 2.46(3H, s, SCH$_3$), 5.92 (2H, s, CH$_2$), 6.66-6.83(4H, m, arom and olefinic), 6.91-7.33(3H, m, ArH+thiophene H). (Found: C, 60.72; H, 4.46. C$_{14}$H$_{12}$O$_2$S$_2$ requires: C, 60.84; H, 4.38%); m/z 276(100%, M$^+$); 228(84).

2-Methylthio-4-(2-chlorostyryl)thiophene (73d) was isolated as viscous yellow liquid, yield 66%; $\nu_{\text{max}}$ 1628, 1585, 1463, 1436 cm$^{-1}$; $\delta_{\text{H}}$ 2.49 (3H, s, SCH$_3$), 6.79-7.66(8H, m, ArH+olefinic+thiophene H). (Found: C, 58.41; H, 3.99. C$_{13}$H$_{11}$ClS$_2$ requires: C, 58.52; H, 4.16%); m/z 268 and 266 (15, 100%, M$^+$).

3-Methyl-2-methylthio-4-styrylthiophene (73e) was isolated as viscous liquid, yield 67%; $\nu_{\text{max}}$ 1592, 1488, 1440, 1372 cm$^{-1}$; $\delta_{\text{H}}$ 2.28(6H, s, CH$_3$ and SCH$_3$), 6.84(2H, brs, olefinic), 6.94-7.43(6H, m, ArH+thiophene H). (Found: C, 68.59; H, 6.11. C$_{14}$H$_{14}$S$_2$ requires: C, 68.25; H, 5.73%); m/z 246(100%, M$^+$), 198(72).
3-Methyl-2-methylthio-4-(4-methoxystyryl)thiophene (73f) was isolated as light yellow solid (hexane), yield 68%; m.p. 85-86°C; $\nu_{\text{max}}$ 1591, 1560, 1498, 1426 cm$^{-1}$; $\delta_H$ 2.30(3H,s,CH$_3$), 2.32(3H,s,SCH$_3$), 6.67-6.83 (4H,m,ArH+olefinic), 7.16-7.38(3H,m,ArH+thiophene H). (Found: C,65.06; H,5.90. C$_{15}$H$_{16}$O$_2$S requires: C,65.18; H,5.84%); m/z 276 (100%,M$^+$), 228(58).

3-Methyl-2-methylthio-4(3,4-methylenedioxystyryl)thiophene (73g) was isolated as light yellow solid (hexane), yield 64%; m.p. 55-56°C; $\nu_{\text{max}}$ 1591, 1490, 1479, 1436 cm$^{-1}$; $\delta_H$ 2.21(3H,s,CH$_3$), 2.23(3H,s,SCH$_3$), 5.88(2H,s,CH$_2$), 6.48-6.87(4H,m,arom and olefinic), 6.90(1H,s,thiophene H), 7.17(1H,s,arom). (Found: C,61.93; H,4.98. C$_{15}$H$_{14}$O$_2$S$_2$ requires: C,62.04; H,4.86%); m/z 290(100%,M$^+$), 242(86).

2-Methylthio-4(4-phenyl-1,3-butadienyl)thiophene(73h) was isolated as colourless crystalline solid (hexane), yield 65%; m.p. 89-90°C; $\nu_{\text{max}}$ 1479, 1440, 1303 cm$^{-1}$; $\delta_H$ 2.47(3H,s,SCH$_3$), 6.50-6.80(4H,m,olefinic), 7.03-7.40(7H,m,ArH+thiophene H). (Found: C,69.80; H,5.58. C$_{15}$H$_{14}$S$_2$ requires: C,69.72; H,5.46%); m/z 258(100%,M$^+$), 210(77).

2-Methylthio-4-[4-(4-methoxyphenyl)-1,3-butadienyl]thiophene (73i) was isolated as light yellow crystalline solid (dichloromethane/hexane), yield 67%; m.p. 147-148°C; $\nu_{\text{max}}$ 1596, 1500, 1299, 1243 cm$^{-1}$; $\delta_H$ 2.47 (3H,s,SCH$_3$), 3.76(3H,s,OCH$_3$), 6.47-6.73(4H,m,olefinic), 6.84(2H,d,J=8.5Hz, arom), 7.09(1H,brs,thiophene H), 7.22(1H,brs,thiophene H), 7.39(2H,d, J=8.5Hz,arom). (Found: C,66.53; H,5.67. C$_{16}$H$_{16}$O$_2$S$_2$ requires: C,66.63; H,5.59%); m/z 288(100%,M$^+$), 240(37).
2-Methylthio-4-[4-(3,4-methylenedioxyphenyl)-1,3-butadienyl]thiophene (73j) was isolated as light yellow crystalline solid (dichloromethane/hexane), yield 63%; m.p. 102°C; $\nu_{\text{max}}$ 1489, 1444, 1259 cm$^{-1}$; $\delta_H$ 2.49 (3H, s, SCH$_3$), 5.93 (2H, s, CH$_2$), 6.43-6.67 (4H, m, olefinic), 6.72-6.83 (2H, m, arom), 6.92 (1H, s, arom), 7.08 (1H, brs, thiophene H), 7.19 (1H, brs, thiophene H). (Found: C, 63.49; H, 4.52. C$_{16}$H$_{14}$O$_2$S$_2$ requires: C, 63.55; H, 4.67%); m/z 302 (100%, M$^+$), 254 (42).

3-Methyl-2-methylthio-(4-phenyl-1,3-butadienyl)thiophene (73k) was isolated as white crystalline solid (hexane), yield 62%; m.p. 98-99°C; $\nu_{\text{max}}$ 1584, 1489, 1479, 1426 cm$^{-1}$; $\delta_H$ 2.30 (3H, s, CH$_3$), 2.35 (3H, s, SCH$_3$), 6.59-6.99 (4H, m, olefinic), 7.20-7.52 (6H, m, ArH+thiophene H). (Found: C, 70.52; H, 5.99. C$_{16}$H$_{16}$S$_2$ requires: C, 70.54; H, 5.92%); m/z 272 (100%, M$^+$), 224 (73).

3-Ethyl-2-methylthio-4-[4-(3,4-methylenedioxyphenyl)-1,3-butadienyl]thiophene (731) was isolated as light yellow crystalline solid (hexane), yield 63%; m.p. 112°C; $\nu_{\text{max}}$ 1589, 1499, 1481, 1436, 1347 cm$^{-1}$; $\delta_H$ 2.28 (3H, s, CH$_3$), 2.35 (3H, s, SCH$_3$), 5.91 (2H, s, CH$_2$), 6.48-6.73 (4H, m, olefinic), 6.80 (2H, brs, arom), 7.94 (1H, brs, arom), 7.27 (1H, brs, thiophene H). (Found: C, 64.61; H, 5.19. C$_{17}$H$_{16}$O$_2$S$_2$ requires: C, 64.52; H, 5.10%); m/z 316 (100%, M$^+$), 268 (42).

3-n-Butyl-2-methylthio-4-[4-(4-methoxyphenyl)-1,3-butadienyl]thiophene (73m) was isolated as light yellow solid (hexane), yield 60%; m.p. 79-80°C; $\nu_{\text{max}}$ 1598, 1508, 1460, 1438 cm$^{-1}$; $\delta_H$ 0.95 (3H, distorted t, CH$_3$), 1.25-1.62 (4H, m, CH$_2$(CH$_2$)$_2$CH$_3$), 2.36 (3H, s, SCH$_3$), 2.73 (2H, t, CH$_2$(CH$_2$)$_2$CH$_3$), 3.77 (3H, s, OCH$_3$), 6.34-6.91 (6H, m, arom and olefinic),
7.28-7.43 (2H, m, arom), 7.30 (1H, s, thiophene H). (Found: C, 69.82; H, 7.08. C_{20}H_{24}O_{2}S_{2} requires: C, 69.76; H, 6.97%); m/z 344 (100%, M⁺).

3-Methyl-2-methylthio-4-[3-(3,4-dimethoxyphenyl)-2-propenyl]thiophene (76a) was isolated as colourless crystalline solid (hexane), yield 61%; m.p. 64-65°C; ν_max 1604, 1586, 1517, 1462, 1440 cm⁻¹; S_H 2.21 (3H, brs, vinylic CH₃), 2.34 (3H, s, 3-CH₃), 2.42 (3H, s, SCH₃), 3.94 (6H, s, OCH₃), 6.49 (1H, brs, arom), 6.94 (3H, brs, arom and vinylic), 7.14 (1H, s, thiophene H). (Found: C, 63.80; H, 6.32. C_{17}H_{20}O_{2}S_{2} requires: C, 63.71; H, 6.29%); m/z 320 (100%, M⁺), 258 (49).

3-Methyl-2-methylthio-4-(5-phenyl-2,4-pentadienyl)thiophene (76b) was isolated as viscous liquid, yield 58%; ν_max 1589, 1483, 1440, 1425, 1370, 1309 cm⁻¹; S_H 2.10 (3H, brs, CH₃), 2.24 (3H, s, 3-CH₃), 2.26 (3H, s, SCH₃), 6.10-6.59 (3H, m, olefinic), 6.88-7.39 (6H, m, ArH+thiophene H). (Found: C, 71.40; H, 6.42. C_{17}H_{18}S_{2} requires: C, 71.28; H, 6.33%); m/z 286 (100%, M⁺), 238 (39), 224 (40).

2-Methylthio-4-(6-phenyl-1,3,5-hexatrienyl)thiophene (73n) was isolated as light yellow crystalline solid (dichloromethane/hexane), yield 69%; m.p. 133-134°C; ν_max 1612, 1580, 1479, 1439, 1410 cm⁻¹; S_H (400 MHz), 2.46 (3H, s, SCH₃), 6.40-6.52 (3H, m, olefinic), 6.58 (1H, d, J=12 Hz, olefinic), 6.65 (1H, dd, J=12 and 8.5 Hz, olefinic), 6.85 (1H, dd, J=12 and 8.5 Hz, olefinic), 7.09 (1H, brs, H-3), 7.20 (1H, brs, H-5), 7.18-7.25 (1H, m, merged with H-5 signal, arom), 7.31 (2H, t, J=8.5 Hz, arom), 7.40 (2H, d, J=8.5 Hz, arom). (Found: C, 71.62; H, 5.72. C_{17}H_{16}S_{2} requires: C, 71.78; H, 5.67%); m/z 284 (100%, M⁺).

2-Methylthio-4-[6-(3,4-methylenedioxyphenyl)-1,3,5-hexatrienyl]thiophene (73o) was isolated as yellow crystalline solid (dichloromethane/
hexane), yield 68%; m.p. 142-143°C; \( \nu_{\text{max}} \) 1628, 1509, 1498, 1451, 1260 cm\(^{-1} \); \( \delta_H \) 2.48(3H,s,SCH\(_3\)), 5.95(2H,s,CH\(_2\)), 6.24-6.63(6H,m,olefinic), 6.72-7.27(5H,m,ArH+thiophene H). (Found: C, 65.69; H, 4.82. \( \text{C}_{18}\text{H}_{16}\text{O}_{2}\text{S}_{2} \) requires: C, 65.82; H, 4.91%); m/z 328(100%,M\(^+\)).

3-Methyl-2-methylthio-4-[6-(3,4-methylenedioxyphenyl)-1,3,5-hexatrienyl] thiophene (73p) was isolated as yellow crystalline solid (dichloromethane/hexane), yield 70%; m.p. 109°C; \( \nu_{\text{max}} \) 1601, 1480, 1435, 1352, 1251, 1235 cm\(^{-1} \); \( \delta_H \) 2.29(3H,s,CH\(_3\)), 2.36(3H,s,SCH\(_3\)), 5.92(2H,s,CH\(_2\)), 6.31-6.99(9H,m,olefinic and aromatic), 7.27(1H,s,thiophene H). (Found: C, 66.72; H, 5.21. \( \text{C}_{19}\text{H}_{18}\text{O}_{2}\text{S}_{2} \) requires: C, 66.63; H, 5.30%); m/z 342(100%,M\(^+\)).

2-Methylthio-4-(2-phenyl)cyclopropylthiophene (80a) was isolated as viscous liquid, yield 57%; \( \nu_{\text{max}} \) 1600, 1531, 1492, 1459, 1412 cm\(^{-1} \); \( \delta_H \) 1.24(2H,distorted t, J=7.0Hz,cyclopropyl CH\(_2\)), 2.00(2H,t, J=7.0Hz, cyclopropyl CH), 2.37(3H,s,SCH\(_3\)), 6.76(2H,brs,H-3 and H-5), 6.93-7.29 (5H,m,arom). (Found: C, 68.56; H, 6.07. \( \text{C}_{14}\text{H}_{14}\text{S}_{2} \) requires: C, 68.25; H, 5.73%); m/z 246(100%,M\(^+\)).

2-Methylthio-4-[2-(4-methoxyphenyl)cyclopropyl]thiophene (80b) was isolated as light yellow viscous liquid, yield 59%; \( \nu_{\text{max}} \) 1617, 1519, 1470, 1445 cm\(^{-1} \); \( \delta_H \) 1.16(2H,t, J=7.0Hz,cyclopropyl CH\(_2\)), 1.93(2H,t, J=7.0Hz,cyclopropyl CH), 2.37(3H,s,SCH\(_3\)), 3.62(3H,s,OCH\(_3\)), 6.59-6.76 (4H,m,aromatic,H-3 and H-5), 6.90(2H,d,J=8.5Hz,arom). (Found: C, 65.09; H, 5.91. \( \text{C}_{15}\text{H}_{16}\text{O}_{5}\text{S}_{2} \) requires: C, 65.18; H, 5.84%); m/z 276(100%,M\(^+\)), 229(33).

3-Methyl-2-methylthio-4-[2-(3,4-methylenedioxyphenyl)cyclopropyl] thiophene (80c) was isolated as light yellow viscous liquid, yield 61%.
\( \gamma_{\text{max}} \) 1605, 1501, 1490, 1460, 1440 cm\(^{-1}\); \( S_H \) 1.17 (2H, distorted t, J=7.0 Hz, cyclopropyl CH\(_2\)), 1.83 (2H, distorted t, J=7.0 Hz, cyclopropyl CH), 2.22 (3H, s, CH\(_3\)), 2.29 (3H, s, SCH\(_3\)), 5.78 (2H, s, CH\(_2\)), 6.50-6.54 (3H, m, arom), 6.70 (1H, s, H-5). (Found: C, 63.46; H, 5.62. C\(_{16}\)H\(_{16}\)O\(_2\)S\(_2\) requires: C, 63.13; H, 5.30%); m/z 304 (100%, M\(^+\)).

2-Methylthio-4-[2-(styryl)cyclopropyl]thiophene (80d) was isolated as viscous yellow liquid, yield 54%; \( \gamma_{\text{max}} \) 1640, 1597, 1530, 1487, 1440, 1410 cm\(^{-1}\); \( S_H \) 0.92-1.21 (2H, m, cyclopropyl CH\(_2\)), 1.45-1.91 (2H, m, cyclopropyl CH), 2.31 (3H, s, SCH\(_3\)), 5.64 (1H, dd, J=16 and 7.5 Hz, CH=CHAr), 6.31 (1H, d, J=16 Hz, CH=CHAr), 6.63 (1H, brs, H-3), 7.06 (6H, brs, arom and H-5). (Found: C, 70.84; H, 6.23. C\(_{16}\)H\(_{16}\)O\(_2\)S\(_2\) requires: C, 70.54; H, 5.92%); m/z 272 (100%, M\(^+\)), 225 (22).

2-Methylthio-4-[2-(4-phenyl-1,3-butadienyl)cyclopropyl]thiophene (80e) was isolated as viscous yellow liquid, yield 56%; \( \gamma_{\text{max}} \) 1636, 1590, 1530, 1458, 1410 cm\(^{-1}\); \( S_H \) 0.80-1.23 (2H, m, cyclopropyl CH\(_2\)), 1.37-1.89 (2H, m, cyclopropyl CH), 2.31 (3H, s, SCH\(_3\)), 5.27 (1H, dd, J=16 and 7.5 Hz, CH=CH=CH=CHAr), 5.95-6.63 (3H, m, olefinic), 6.92 (1H, s, H-3), 6.88-7.27 (6H, m, arom and H-5). (Found: C, 72.73; H, 6.42. C\(_{18}\)H\(_{18}\)O\(_2\)S\(_2\) requires: C, 72.44; H, 6.08%); m/z 298 (84%, M\(^+\)).

Desulphurisation of thiophenes (49a-c, 49j, 73n,p and 76a); General Procedure:

To a solution of methylthiothiophene (0.004 mol) in methanol (30 ml) was added Raney-Nickel (W-2) (ca. 10 times by weight) and the mixture was stirred at room temperature for 3-5 hr. (monitored by t.l.c.). The reaction mixture was filtered and the residue was washed with hot
methanol (3x20 ml). The bulk of the methanol was removed under reduced pressure and chloroform (30 ml) was added. This solution was washed with water (2x50 ml), dried and evaporated. Analytically pure compounds were obtained by passing through short length silica gel column using pentane as eluent.

3-Phenylthiophene (50a) was isolated as colourless crystals (pentane), yield 52%; m.p. 89-90°C; $\nu_{\text{max}}$ 1589, 1482, 1440, 1192 cm$^{-1}$; $\delta_{\text{H}}$ 7.13-7.38 (6H, m, ArH and thiophene H), 7.39-7.58 (2H, m, ArH). (Found: C, 75.12; H, 5.10. C$\text{\textsubscript{10}}$H$\text{\textsubscript{8}}$S requires: C, 74.96; H, 5.03%); m/z 160(100%, M$^+$), 115(49).

3-(4-Methylphenyl)thiophene (50b) was isolated colourless crystals (pentane), yield 58%; m.p. 108-109°C; $\nu_{\text{max}}$ 1499, 1370, 1305, 1193 cm$^{-1}$; $\delta_{\text{H}}$ 2.36 (3H, s, CH$_3$), 7.17 (2H, d, $J$=8.5 Hz, A$\text{\textsubscript{2}}$B$\text{\textsubscript{2}}$, ArH), 7.36 (3H, brs, thiophene H), 7.49 (2H, d, $J$=8.5 Hz, A$\text{\textsubscript{2}}$B$\text{\textsubscript{2}}$, ArH); $\delta_{\text{C}}$ 21.01 (CH$_3$), 119.59, 125.92, 126.40 (CH, thiophene), 126.34, 129.44 (CH, ArH), 133.20 (C-3, thiophene), 136.76, 142.42 (C-1' and C-4' ArH). (Found: C, 75.86; H, 5.84. C$\text{\textsubscript{11}}$H$\text{\textsubscript{10}}$S requires: C, 75.81; H, 5.78%); m/z 174(100%, M$^+$).

3-(4-Chlorophenyl)thiophene (50c) was isolated as colourless crystals (pentane), yield 59%; m.p. 95-96°C; $\nu_{\text{max}}$ 1591, 1525, 1483, 1416, 1200 cm$^{-1}$; $\delta_{\text{H}}$ 7.20-7.50 (7H, m, ArH). (Found: C, 61.60; H, 3.56. C$\text{\textsubscript{10}}$H$_7$ClS requires: C, 61.69; H, 3.62%); m/z 196, 194(39, 100%, M$^+$).

2,3-Diphenylbutane (51) was isolated as colourless crystals (pentane), yield 62%; m.p. 125°C; $\nu_{\text{max}}$ 1599, 1488, 1444 cm$^{-1}$; $\delta_{\text{H}}$ 1.01 (6H, d, $J$=6.0 Hz, CH$_3$), 2.66-2.94 (2H, m, CHCH$_3$), 7.24 (10H, brs, ArH). (Found: C, 91.22; H, 8.53. C$\text{\textsubscript{16}}$H$\text{\textsubscript{18}}$ requires: C, 91.37; H, 8.63%); m/z 210(22%, M$^+$), 105(100).
5-(3,4-Dimethoxyphenyl)-2,3,4-trimethylpentane (77) was isolated as colourless liquid; yield 72%; \( \nu \)\text{max} 1600, 1580, 1505, 1460, 1411 cm\(^{-1}\); \( \delta_H \) 0.67-1.17(9H,m,CH\(_3\)), 1.26-2.05(8H,m,CH\(_2\),CH\(_3\) and CH), 6.51-6.77 (3H,m,ArH). (Found: C,76.89; H,10.61. \( \text{C}_{16}\text{H}_{26}\text{O}_2 \) requires: C,76.75; H,10.47%); m/z 250(15%,\( \text{M}^+ \)).

3-Methyl-9-phenylnonane (78a) was isolated as colourless liquid, yield 70%; \( \nu \)\text{max} 1601, 1545, 1490, 1450 cm\(^{-1}\); \( \delta_H \) 0.72-0.96(6H,m,CH\(_3\)), 1.11-1.73(12H,m,CH\(_2\)), 1.79-2.06(1H,m,CH), 2.56(2H,t,J=7.5Hz,benzylic CH\(_2\)), 7.10(5H,brs,ArH). (Found: C,88.21; H,12.15. \( \text{C}_{16}\text{H}_{26} \) requires: C, 88, H,12%); m/z 218(51%,\( \text{M}^+ \)).

2,3-Dimethyl-9-(3,4-methylenedioxyphenyl)nonane (78b) was isolated as colourless liquid, yield 71%; \( \nu \)\text{max} 1499, 1482, 1439, 1240 cm\(^{-1}\); \( \delta_H \) 0.70-1.04(6H,m,CH\(_3\)), 1.12-1.66(13H,m,CH\(_2\) and CH\(_3\)), 1.77-2.20(2H, m,CH), 2.48(2H,t,J=7.5Hz,benzylic CH\(_2\)), 5.84(2H,s,CH\(_2\)), 6.51-6.64 (3H,m,ArH). (Found: C,78.11; H,10.23. \( \text{C}_{18}\text{H}_{28}\text{O}_2 \) requires: C,78.21; H,10.21%); m/z 276(39%,\( \text{M}^+ \)).
REFERENCES


