Synthesis And Reactions Of Heterocyclic, (alpha,beta)-unsaturated Sulfonium Salts.

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SYNTHESIS AND REACTIONS OF HETEROCYCLIC, α, β -UNSATURATED SULFONIUM SALTS

by

Richard A. Lazarus

A DISSERTATION
Presented to the Graduate Faculty of
Lehigh University in Candidacy for
the Degree of Doctor of Philosophy

Lehigh University
1968

This dissertation is respectfully submitted to the Graduate Faculty of Lehigh University, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Richard A. Lazarus

Richard A. Lazarus

A CERTIFICATE OF APPROVAL

Approved and recommended for acceptance as a dissertation in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

May 15, 1968
Date

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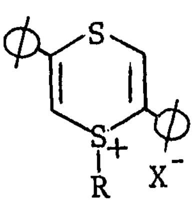
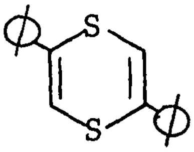
Abstract

Recent interest in the nature and degree of sulfur 3d orbital participation in forming $d\pi$-$p\pi$ bonds has led to the synthesis and study of a new class of sulfonium compounds, the 1-alkyl-2,5-diphenyl-1,4-dithiinium salts (I). These new sulfonium salts were synthesized by alkylation of 2,5-diphenyl-1,4-dithiin (II) with methyl, methyl-d_3, and ethyl iodides in the presence of silver 2,4,6-trinitrobenzenesulfonate, mercuric iodide, silver perchlorate, or silver tetrafluoroborate to give high yields of the desired products.



I

	R	X^-
a.	Me	$TNBS^-$
b.	Me	HgI_3^-
c.	Me	ClO_4^-
d.	Me	BF_4^-
e.	CD_3	BF_4^-
f.	Et	$TNBS^-$
g.	Et	ClO_4^-



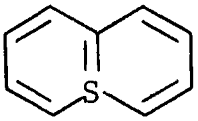
II

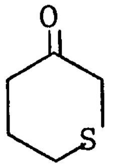
$TNBS^-$ is 2,4,6-trinitrobenzenesulfonate

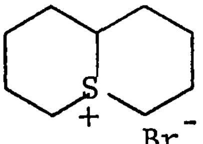
1-Methyl-2,5-diphenyl-1,4-dithiinium tetrafluoroborate was readily demethylated by common nucleophiles such as dimethyl sulfide, piperidine, thioanisole, ethoxide, hydroxide, iodide, and bromide. n-Butyllithium also demethylated the tetrafluoroborate salt (Id). In addition the salt was further attacked at S-4 by n-butyllithium with ring scission to form phenylacetylene and a mixture of cis-and trans-1-butylthio-2-methylthio-1-phenylethylene, which was also synthesized by an unambiguous route from the reaction of methyl phenacyl sulfide and 1-butanethiol in the presence of p-toluenesulfonic acid with azeotropic water separation. Sodium hydride selectively abstracted the H-3 proton of the tetrafluoroborate salt (Id) to yield quantitatively the ring-cleavage product, 1-phenylethynylthio-2-methylthio-1-phenylethylene, and the methyl-d_3 analog (Ie) behaved similarly to give 99% isotopically pure 1-phenylethynylthio-2-trideuteriomethylthio-1-phenylethylene. The nmr spectra of the 1-alkyl-2,5-diphenyl-1,4-dithiinium salts (I) revealed that H-3 of the dithiinium ring is strongly deshielded (δ 8.75) via 3d-orbital conjugation of the sulfonium center, while H-6 remains more normally olefinic (δ 6.90) suggesting a lack of cyclic delocalization. In addition the nmr spectrum of 1-methyl-3-bromo-2,5-diphenyl-1,4-dithiinium perchlorate exhibits a nearly normal olefinic proton (δ 7.08).

It was of interest also to synthesize a compound with sulfur at a bridgehead with three $2p\pi$ carbon atoms attached to the sulfur atom as part of a conjugated π system. A structure which has the above-mentioned requirements is

4a-thianaphthalene (III). The synthesis of a 4a-thianaphthalene was to be accomplished by forming a second ring on tetrahydrothiapyran-3-one (IV).

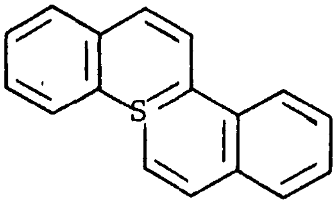

III

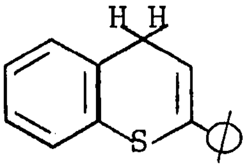

IV

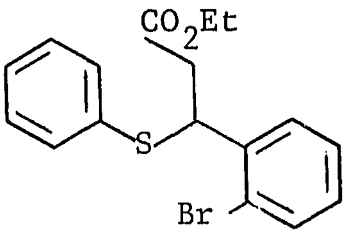


V

However, attempts to prepare either an alkylidene derivative or to C-alkylate the sodium enolate of ketone IV resulted in tar formation or undesired products. The morpholino enamine of ketone IV was easily prepared but acylation of the enamine failed. Attempted dehydrogenation of bicyclo [4.4.0] decane-1-thianium bromide (V), prepared from acyclic intermediates, gave only tar. The synthesis of 4b-thiachysene (VI) was to be accomplished by the addition of a substituted or unsubstituted two carbon fragment to a 2-phenylbenzothiapyran derivative such as 2-phenyl-4H-(1)-benzothiapyran (VII).


VI

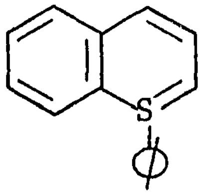

VII


VIII

However, attempted alkylation of VII with phenacyl bromide in the presence of AgTNBS resulted instead in aromatization of VII to 2-phenylthianaphthalenium 2,4,6-trinitrobenzenesulfonate. In another attempt to prepare 4b-thiachrysene by first synthesizing ethyl 3-phenylthio-3-(2-bromophenyl) propionate (VIII), an unexpected but interesting reaction occurred. When ethyl 2-bromocinnamate was treated with thiophenol in DMF, the aryl halogen was displaced to give ethyl 2-phenylthiocinnamate instead of the desired Michael adduct, compound VIII.

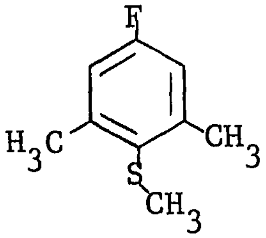
Introduction

It has been established on a theoretical basis that second row elements can expand their valence shells to form multiple bonds.[1,2] Recent interest in the ability of sulfur to expand its valence shell to include the 3d level[3] has manifested itself in the synthesis of a new class of compounds by Price.[4,5,6,7] A typical member of this thiaaromatic class, 1-phenyl-1-thianaphthalene (I), has been shown to be pseudoaromatic by nmr and dipole moment data.[7]



I

Moreover, Taft[8,9] has shown using ultraviolet-visible spectra and fluorine nmr techniques that there is significant 3d orbital population of the sulfur atom in compounds of the following type:



II

The ultraviolet spectrum of thiophenol has a band at 280 mμ which has been assigned to an $^1L_b \leftarrow {}^1A$

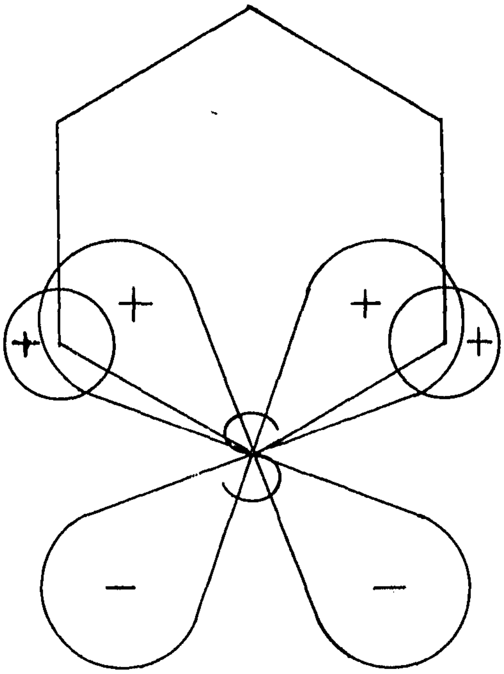
transition. It was determined[8] that if the 3d orbitals of sulfur were involved in bonding to the ring, the intensity of the L_b band in p-methylthiophenol would show a decrease, and that if $3p\pi - 2p\pi$ bonding were involved, the intensity of the L_b band in p-methylthiophenol would show an increase. The resulting spectra showed a distinct decrease in intensity of the L_b band for p-methylthiophenol ($\epsilon \sim 300$) as compared with thiophenol ($\epsilon \sim 700$). On the other hand, comparison of the spectra of phenol ($\epsilon \sim 1320$) with p-methylphenol ($\epsilon \sim 1840$) showed a distinct increase in the intensity of the L_b band. It may be concluded that sulfur 3d orbital participation is important for bonding in thiophenols.

It is well known that increasing the non-planarity of a π electron system results in rapid loss of conjugation because of diminished overlap of the 2p orbitals. Experimentally[8] this has been shown to be true for sterically twisted anisoles since there was a decrease in the intensity of L_b band in the sterically hindered anisole as compared with anisole.

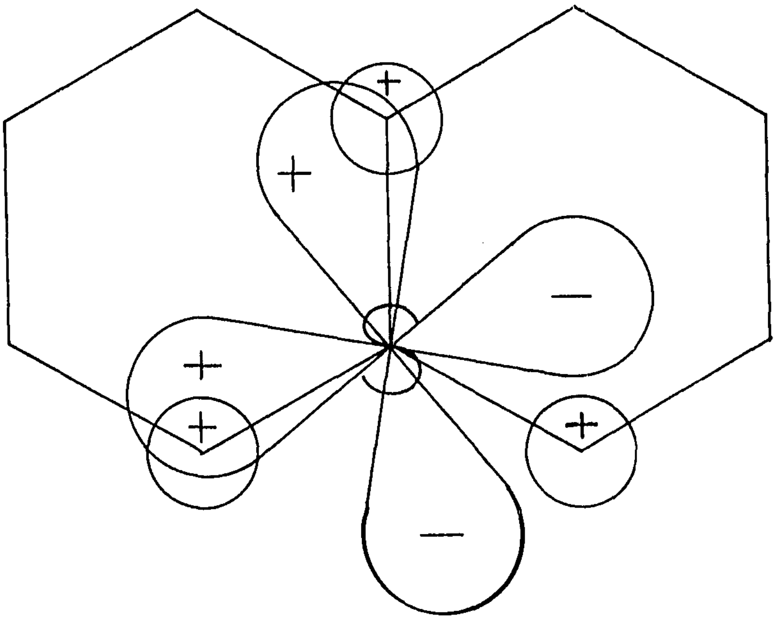
When 4-fluorothioanisole ($\epsilon \sim 900$) was compared with 2,6-dimethyl-4-fluorothioanisole ($\epsilon \sim 1600$) it was found that there was an increase in the intensity of the L_b band for the sterically hindered thioanisole. As was shown before for the thiophenols, the increase in ϵ indicates sulfur 3d orbital participation. Comparison of the anisoles with the thioanisoles revealed that, unlike the planarity with the benzene ring required for the p orbitals of oxygen to overlap the pπ orbitals of carbon, there was little if any angular dependence on sulfur 3d orbitals for efficient overlap with the pπ orbitals of the benzene ring.

The fluorine nmr results[8,9] comparing 2,6-dimethyl-4-fluorothioanisole (II) with 1,3-dimethyl-5-fluorobenzene using fluorobenzene as the internal standard (δ =0) showed that the SCH_3 group, when twisted out of the plane of the benzene ring, became a weak electron acceptor. (The chemical shift of fluorine in II was less than that for fluorobenzene itself). When 2,6-dimethyl-4-fluoroanisole was compared with 1,3-dimethyl-5-fluorobenzene using fluorobenzene as the internal standard (δ =0) it was found that there was a decrease in shielding by the OCH_3 group when it was twisted out of the plane of the benzene ring but that OCH_3 was not an electron acceptor. The fluorine nmr results then are in complete agreement with the ultraviolet-visible spectral results.

Although the exact nature of the bonding is not known,



Sulfur 3d Orbital Overlap with 2 Adjacent Centers



Sulfur 3d Orbital Overlap with 3 Adjacent Centers

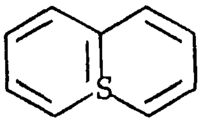
Figure 1

Sulfur 3d Orbital Overlap

with Carbon 2p Orbitals

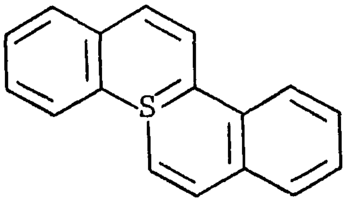
3d orbitals are available and are used for π(p-d) conjugation. Caserio[10] and Taft[8] have shown that rotation about a 3d-2pπ bond should not result in diminished overlap because of the cylindrical symmetry[11] of 3d orbitals. Sulfur 3d orbitals appear to have cylindrical symmetry (as was shown above by Taft) because when one 3d orbital is no longer able to overlap with the pπ system, there is another 3d orbital to take its place. However, the idea of cylindrical symmetry is restricted to overlap of sulfur 3d orbitals with a single adjacent carbon 2p orbital. In order to assess the degree of effective overlap when the sulfur 3d orbitals overlap two or more adjacent carbon 2p orbitals, the geometry of the 3d orbitals involved in forming the potential bond must be considered.

It was of interest then to synthesize a molecule with a sulfur atom at a bridgehead, so that with the conformation of the molecule "frozen," the geometric requirements necessary for sulfur 3d overlap with three adjacent 2pπ orbitals could be studied. (<u>cf</u>. Figure 1) An appropriate system which would meet the above mentioned requirements is 4a-thianaphthalene (III).



III

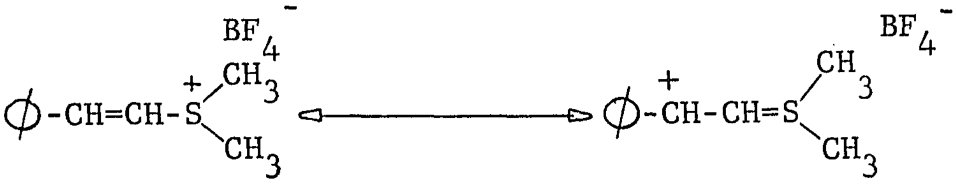
However, attempts to synthesize compound III and its dibenz analog, 4b-thiachrysene (IV),



IV

resulted in the formation of intermediates which could not be converted to compounds III or IV because of unexpected reactions which occurred instead (*cf.* p. 15 of the Results and Discussion section for further details).

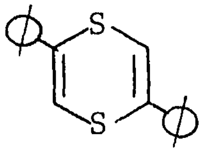
Since Caserio[10] showed by nmr that the β proton in cis-and trans-styryldimethylsulfonium tetrafluoroborate (V)

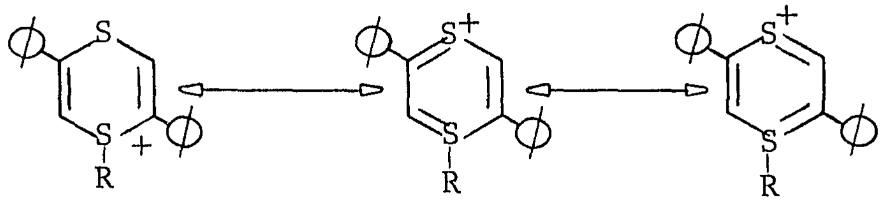


$$\phi\text{-CH=CH-}\overset{+}{S}(CH_3)_2\ BF_4^- \longleftrightarrow \phi\text{-}\overset{+}{C}H\text{-CH=S}(CH_3)_2\ BF_4^-$$

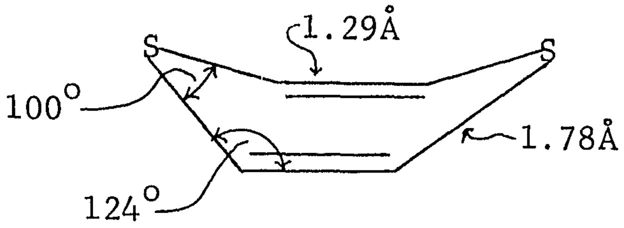
V Va

was more deshielded that the α proton, it was concluded that canonical form Va contributes significantly to the ground state of the molecule. If a more effective donor (namely a sulfur atom) is substituted for the hydrogen atom and if the number of degrees of freedom of the system is reduced by forming a ring, the degree of participation as well as the steric requirements for participation of sulfur 3d orbitals can be studied. A system well suited for such a study is 2,5-diphenyl-1,4-dithiin (VI)[12] and the corresponding sulfonium salt VII.


VI


VII VIIa VIIb

The parent compound, 1,4-dithiin (VIII)[13] is known to have a puckered boat form by X-ray diffraction studies of a single crystal.[14]



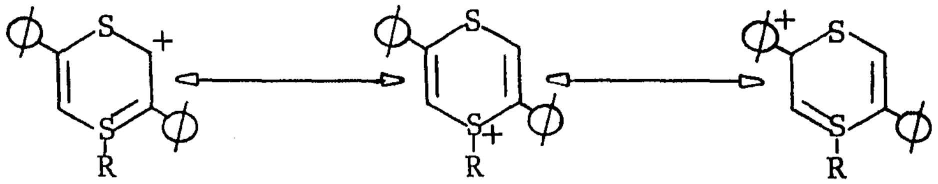
IX

Although 1,4-dithiin is not planar, Kreevoy[15] calculated that the resonance energy of the system would be at a maximum (28 kcal/mol) if the C-S-C bond-angle were about 96°. Even though 1,4-dithiin does not undergo reactions generally associated with aromatic character, 2,5-diphenyl-1,4-dithiin rapidly undergoes substitution in the dithiin nucleus including reactions such as bromination and nitration to give monosubstituted derivatives in about 75% yield, but acetylation of the 2,5-diphenyl-1,4-dithiin nucleus does not occur. Thus it may be concluded that the parent dithiin as well as the more reactive diaryldithiin has little, if any, aromatic character and that canonical forms such as IXb contribute little to the ground state of the molecules.

IXa IXb

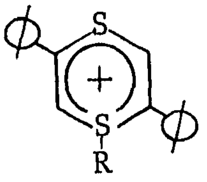
This conclusion is consistent with the statement made by Jaffe[16] in which he wrote, "that expansion does occur when, and only when, the second row atom, without multiple bonds, would be positively charged."

Alkylation of 2,5-diphenyl-1,4-dithiin (VI) would generate a sulfonium center which, by Jaffe's requirement, would allow the now smaller[17] 3d-orbitals on sulfur to accept electrons from the p-π systems which are <u>potentially</u> conjugated with the sulfur atom.



VIIc VII VIId

The carbonium centers at the carbon atoms (VIIc and VIId) could be stabilized by donation of an electron pair from the divalent sulfur atom at the 4-position.[18] However, in order to achieve maximum overlap with the p-π system, five atoms in the skeleton of dithiinium salt VII need to become planar, while the sulfur atom bearing the alkyl group need not become planar to achieve effective d orbital overlap.[8,10,11] (See structures VIIa and VIIb). If canonical forms VIIa and VIIb are important contributors to the ground state of dithiinium ion VII, there would be established a system in which six electrons would be distributed over six atoms. Because of the orthogonal nature of d-orbitals, no cyclic[19] delocalization could occur, but there would be ample opportunity for conjugation.

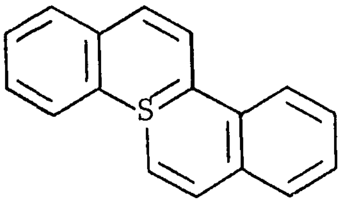


X

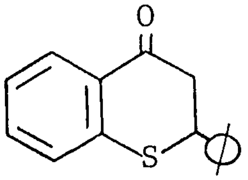
In order to elucidate the possible alternatives outlined above, dithiinium salts were prepared and studied (_cf_. Results and Discussion section p. 41).

Results and Discussion

Attempted Synthesis of Compounds with Sulfur at a Bridgehead. 2-Phenylthiachroman-4-one (XI)[20] was selected as the precursor for the synthesis of 4b-thiachrysene (IV) because of the easy accessibility of XI.



IV



XI

The preparation of 2-phenylthiachroman-4-one (XI) was accomplished in two steps, the first of which was the addition of thiophenol (XII) to cinnamic acid (XIII) to give 3-phenylthio-3-phenylpropionic acid (XIV).[20] Subsequent cyclization of compound XIV to 2-phenylthiachroman-4-one (XI) was effected by the use of phosphorus pentoxide in refluxing toluene.[21] The cyclization step is especially sensitive to moisture, so that all starting materials must be thoroughly dried or a reverse Michael addition reaction will result to yield thiophenol (XII) and cinnamic acid (XIII) as well as intractable resins.[22]

Reduction of ketone XI with lithium aluminum hydride in tetrahydrofuran (THF) at room temperature gave a good yield of 2-phenylthiachroman-4-ol (XV).[23]

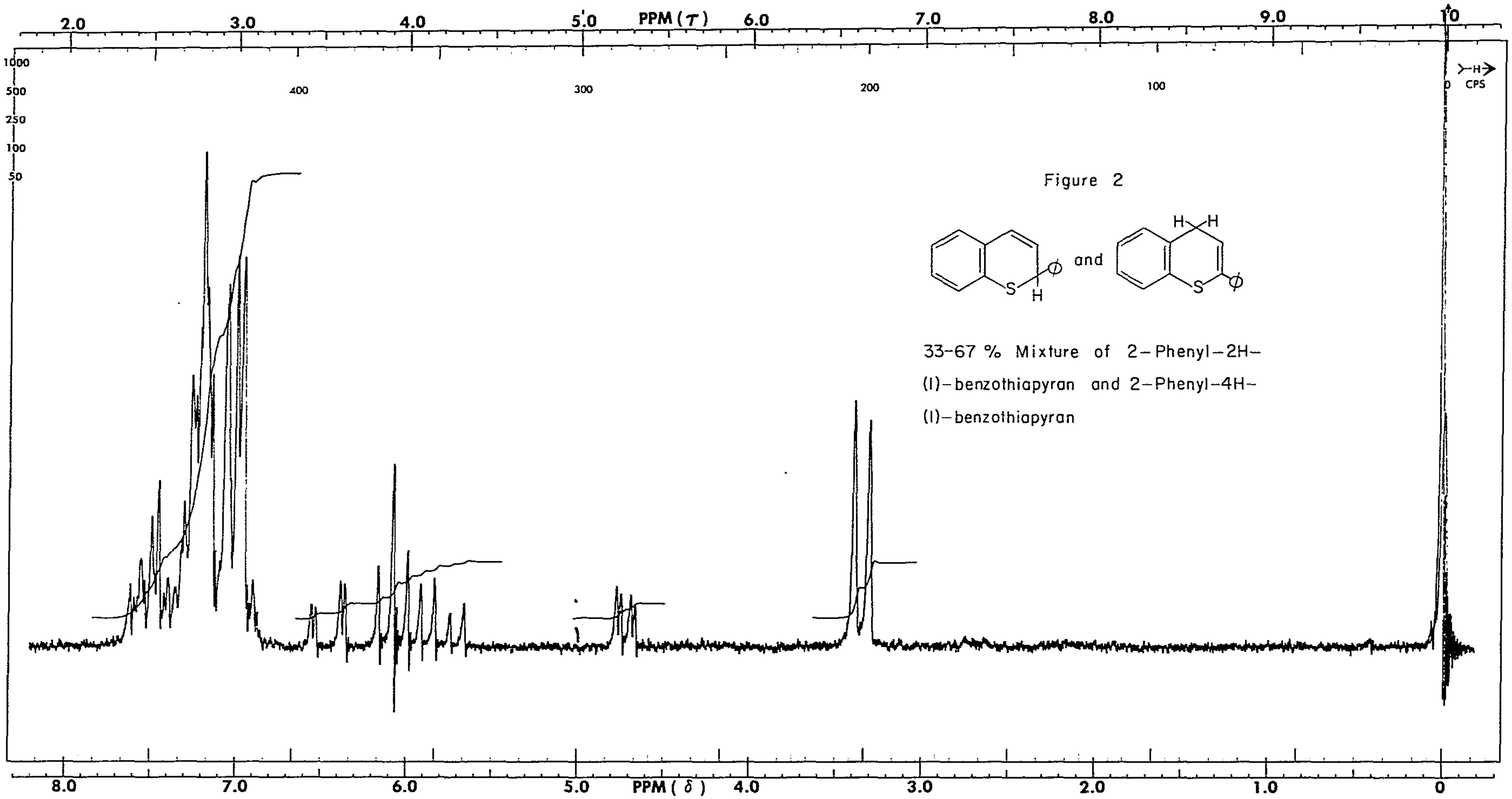
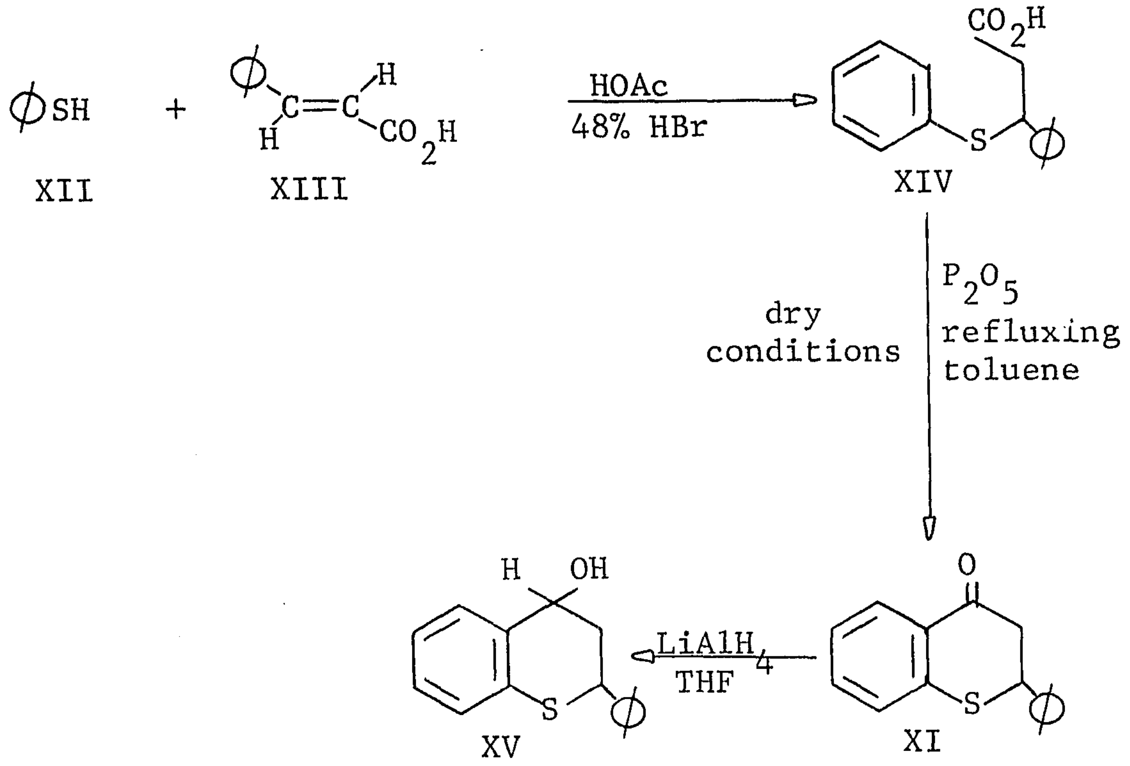
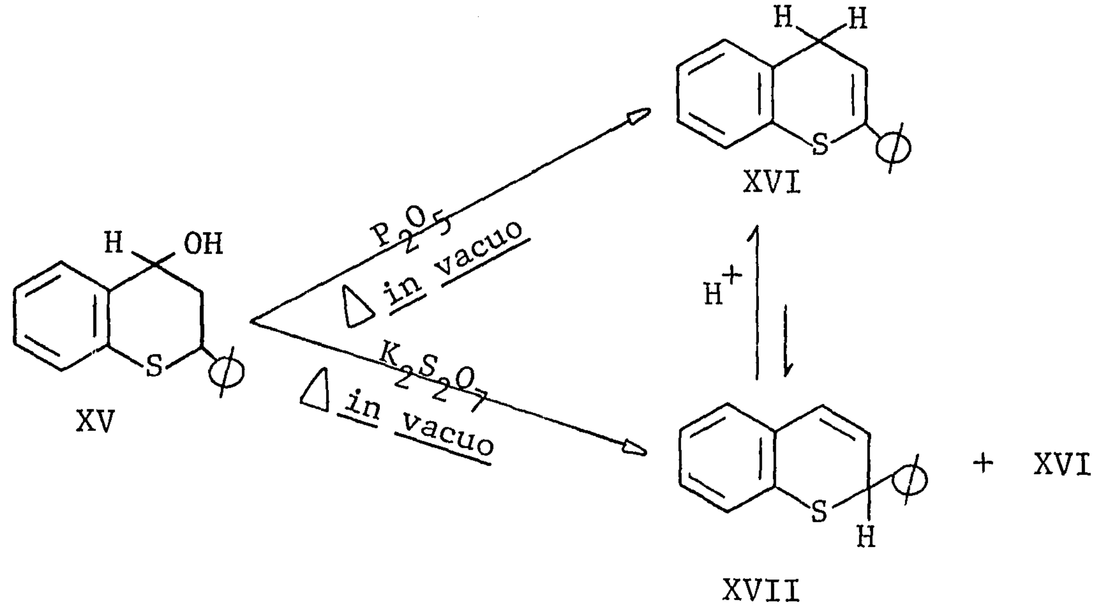


Figure 2

33–67 % Mixture of 2-Phenyl-2H-(I)-benzothiapyran and 2-Phenyl-4H-(I)-benzothiapyran

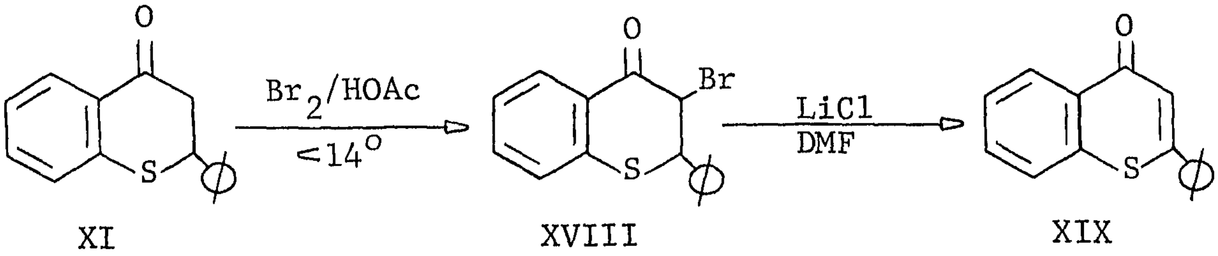


Dehydration of alcohol XV using phosphorus pentoxide according to the method of Luttringhaus[23] gave only 2-phenyl-4H-(1)-benzothiapyran (XVI). If, however, the dehydration is done quickly using fused potassium pyrosulfate[24] as the dehydrating agent, a mixture of XVI and 2-phenyl-2H-(1)-benzothiapyran (XVII) is obtained (determined by nmr, cf. Experimental Section p. 74). A trace of acid will quickly isomerize compound XVII to compound XVI. In a separate experiment, alcohol XV was heated in vacuo with fused potassium pyrosulfate for 30 minutes to allow equilibration to occur. On distillation, a mixture of compounds XVI and XVII was obtained in a ratio of 67%:33% respectively as determined by nmr (cf. Figure 2).

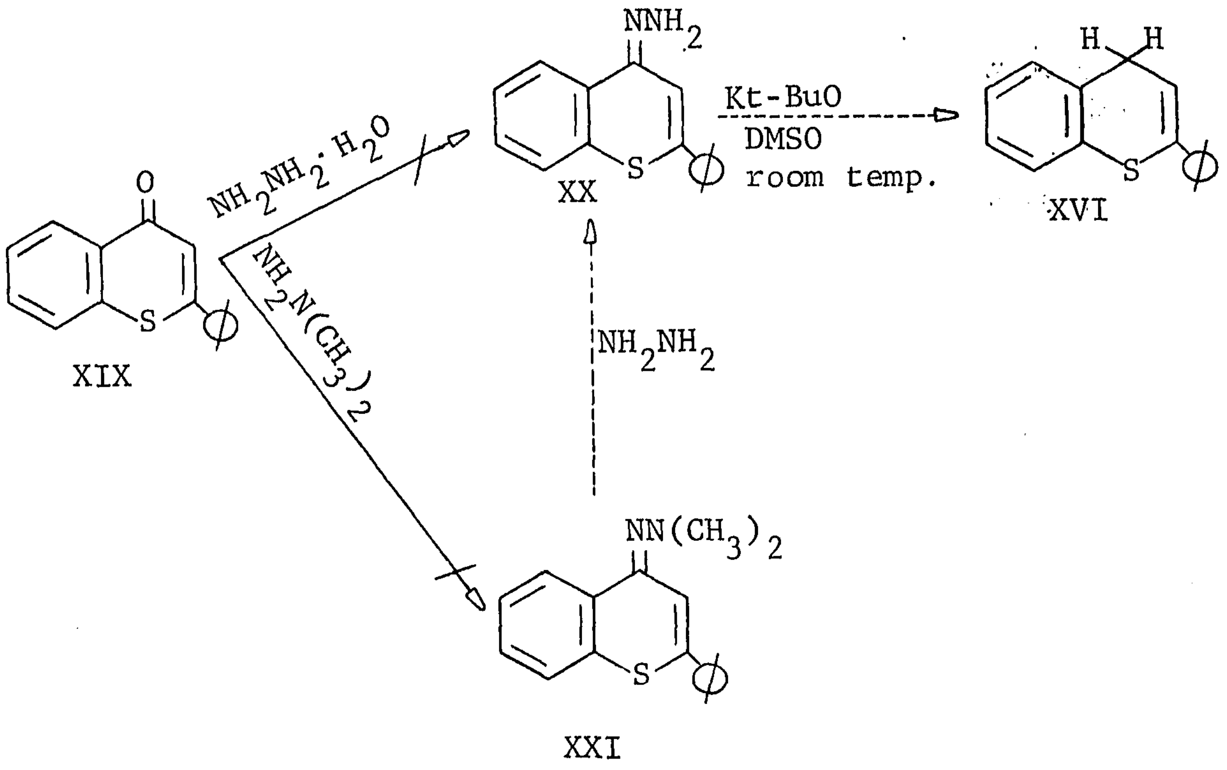


Preparation of compound XVI by a totaly different method was accomplished using a modification of the method of Arndt.[25] 2-Phenyl-3-bromothiachroman-4-one (XVIII) was prepared in fair yield by direct bromination of compound XI in glacial acetic acid. It was found that the quality of the product is improved significantly if the bromination is done at about 14°.[22]

Using the method of Warnhoff,[26] bromoketone XVIII was dehydrohalogenated smoothly with lithium chloride in dimethylformamide (DMF) to give 2-phenylthiachromone (XIX) in good yield.



2-Phenyl-4H-(1)-benzothiapyran (XVI) was to have been prepared *via* a room temperature Wolff-Kishner reduction[27] on the hydrazone. Adaptation of a method used by Curtis and Thun[28] for the preparation of the monohydrazone of benzil using hydrazine hydrate afforded only starting material when applied to ketone XIX. Another method by Newkome and Fishel[29] involving initial formation of an N,N-dimethylhydrazone XXI using unsym-dimethylhydrazine followed by exchange with hydrazine to give the corresponding hydrazone XX also failed. Again, only starting material was recovered from the initial reaction of ketone XIX with the unsym-dimethylhydrazine.



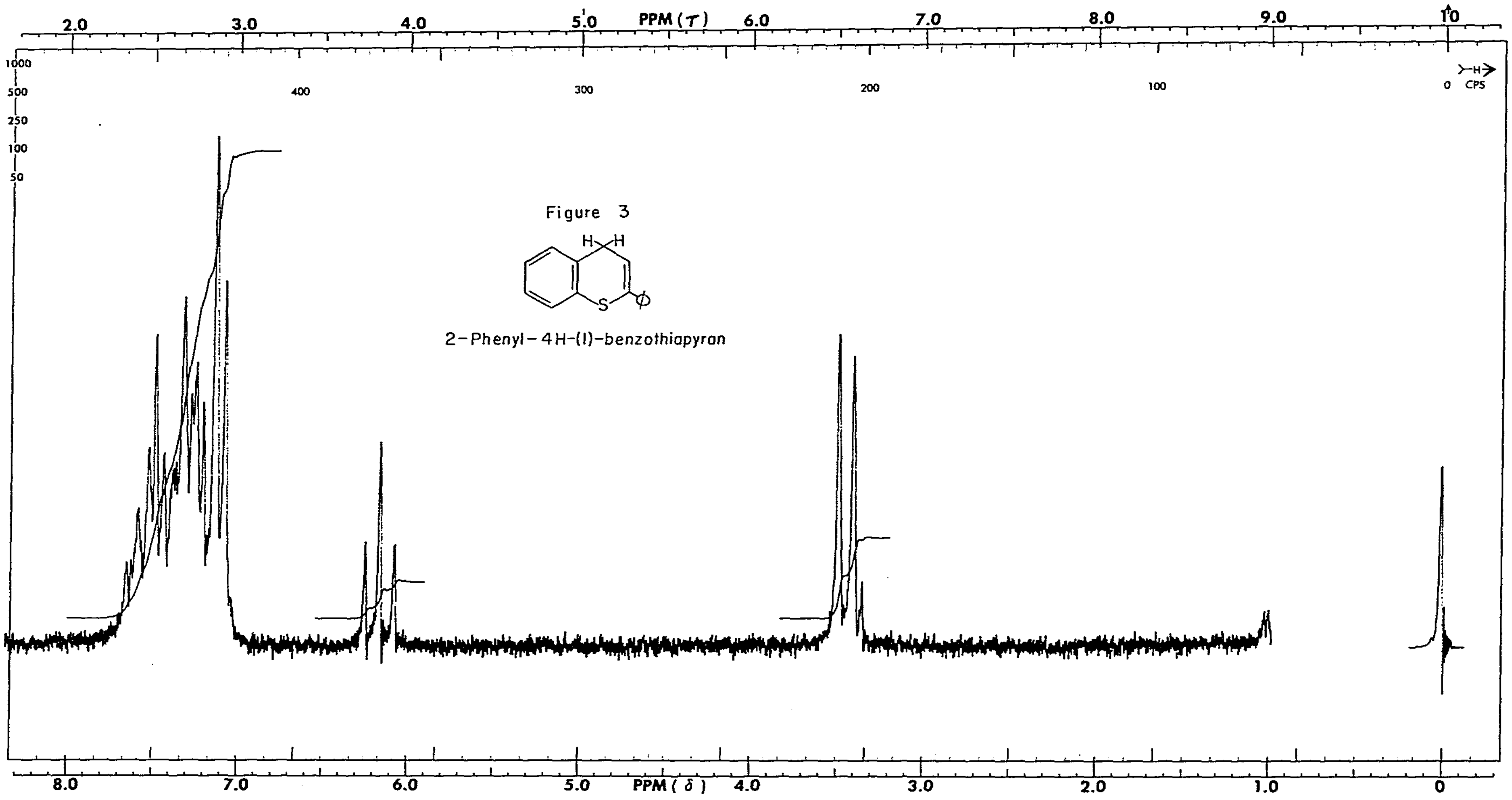
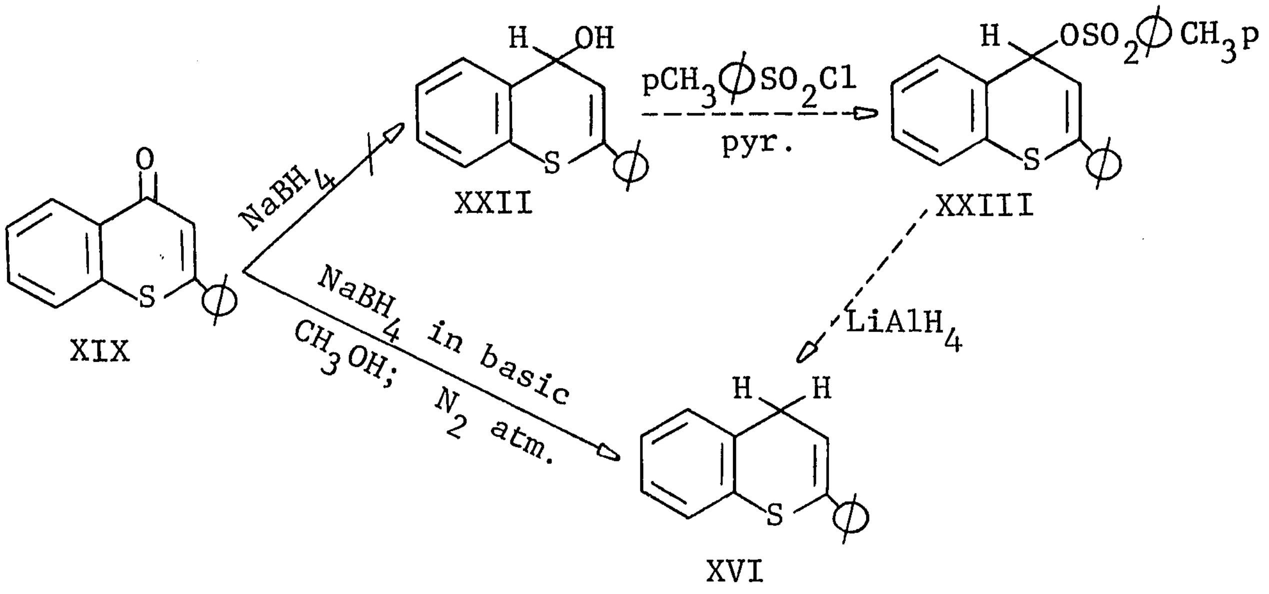


Figure 3

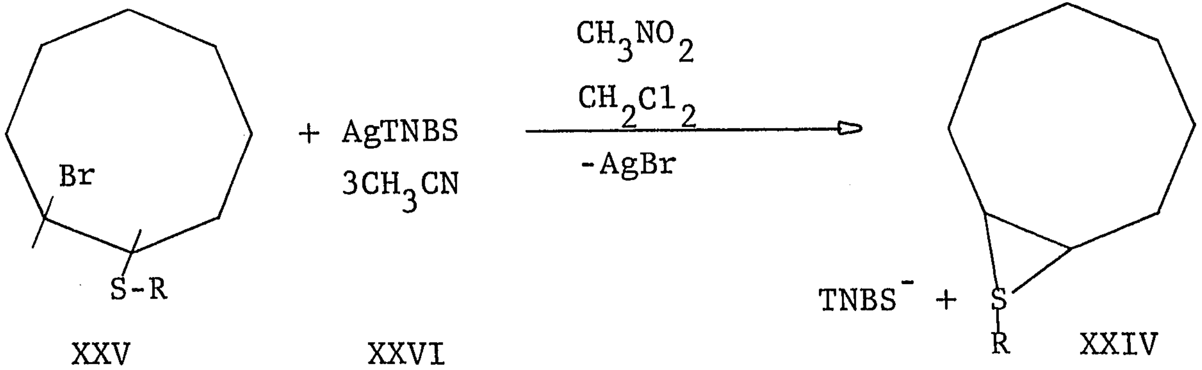
2-Phenyl-4H-(1)-benzothiapyran

An alternative route to compound XVI was devised as follows: reduction of ketone XIX to allylic alcohol XXII using sodium borohydride as the reducing agent; conversion of alcohol XXII to the corresponding tosylate XXIII followed by reduction of tosylate XXIII with lithium aluminum hydride[30] to the desired 2-phenyl-4H-(1)-benzothiapyran (XVI).

When a methanol slurry of ketone XIX was treated with an aqueous solution of sodium borohydride stabilized with sodium hydroxide and refluxed under a nitrogen atmosphere for five hours, the expected allylic alcohol XXII was not formed, but instead only 2-phenyl-4H-(1)-benzothiapyran (XVI) resulted (*cf*. Figure 3). The molar ratio of ketone XIX to sodium borohydride is critical, for it was found that either no reaction occurred or a mixture of ketone XIX and compound XVI resulted if the molar ratio was below 1:3 (ketone XXIII:$NaBH_4$). Optimum results were obtained with a molar ratio of 1:6



In order to obtain the skeleton necessary to complete the synthesis of thiachrysene (IV) from either 2-phenyl-2H-(1)-benzothiapyran (XVII) or 2-phenyl-4H-(1)-benzothiapyran (XVI), or a mixture of the two isomers, alkylation on sulfur to form a sulfonium salt was attempted. A method developed by Pettitt and Helmkamp[31] for the formation of episulfonium salts XXIV from 1-bromo-2-alkylthiocyclooctanes (XXV) and silver 2,4,6-trinitrobenzenesulfonate (AgTNBS) (XXVI) was unsuccessfully employed.



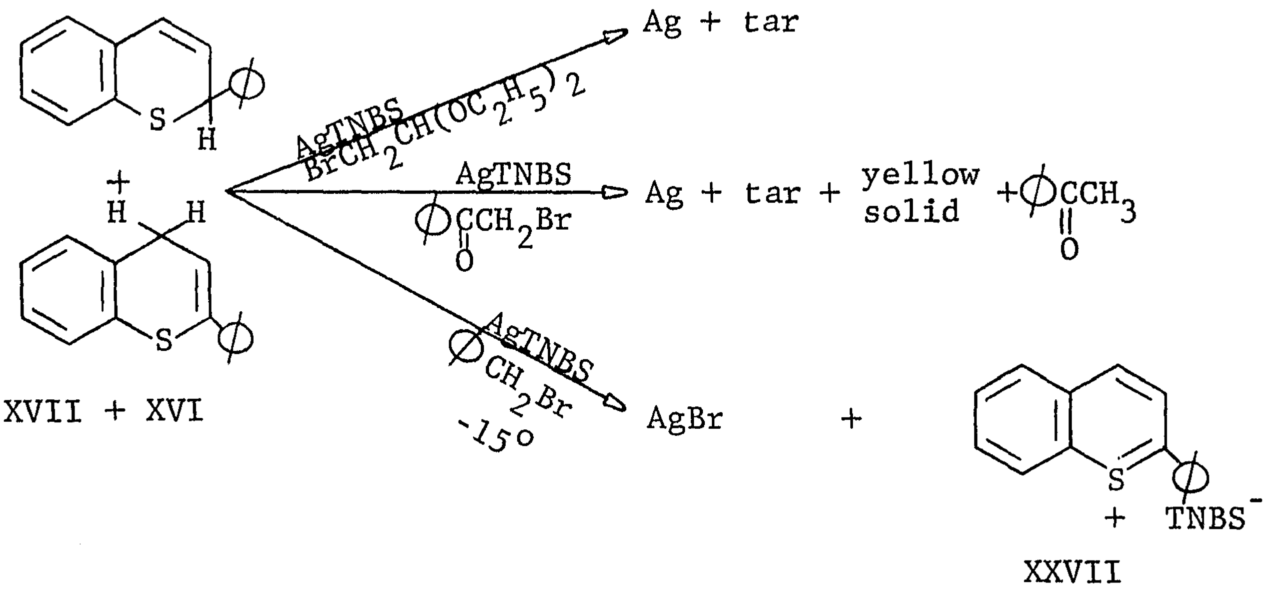
Their reactions were carried out at room temperature in a mixed solvent system of methylene chloride and nitromethane.

The alkylating agent was added to a solution of the AgTNBS (XXVI) followed by the compound to be alkylated.

The first alkylating agent used was diethyl bromoacetal which generated silver metal on contact with the AgTNBS (XXVI).

The reaction was repeated using phenacyl bromide. Again silver metal was formed, but in addition, a small amount of yellow solid, which decomposed above 200°, separated. Tlc of the supernatant liquid indicated the presence of unreacted phenacyl bromide as well as acetophenone. The presence of the high melting yellow solid coupled with the appearance of acetophenone suggested the possibility of the transfer of an hydride ion to the phenacyl bromide from the mixture of compounds XVI and XVII to give the corresponding 2-phenylthianaphthalenium 2,4,6-trinitrobenzenesulfonate (XXVII).

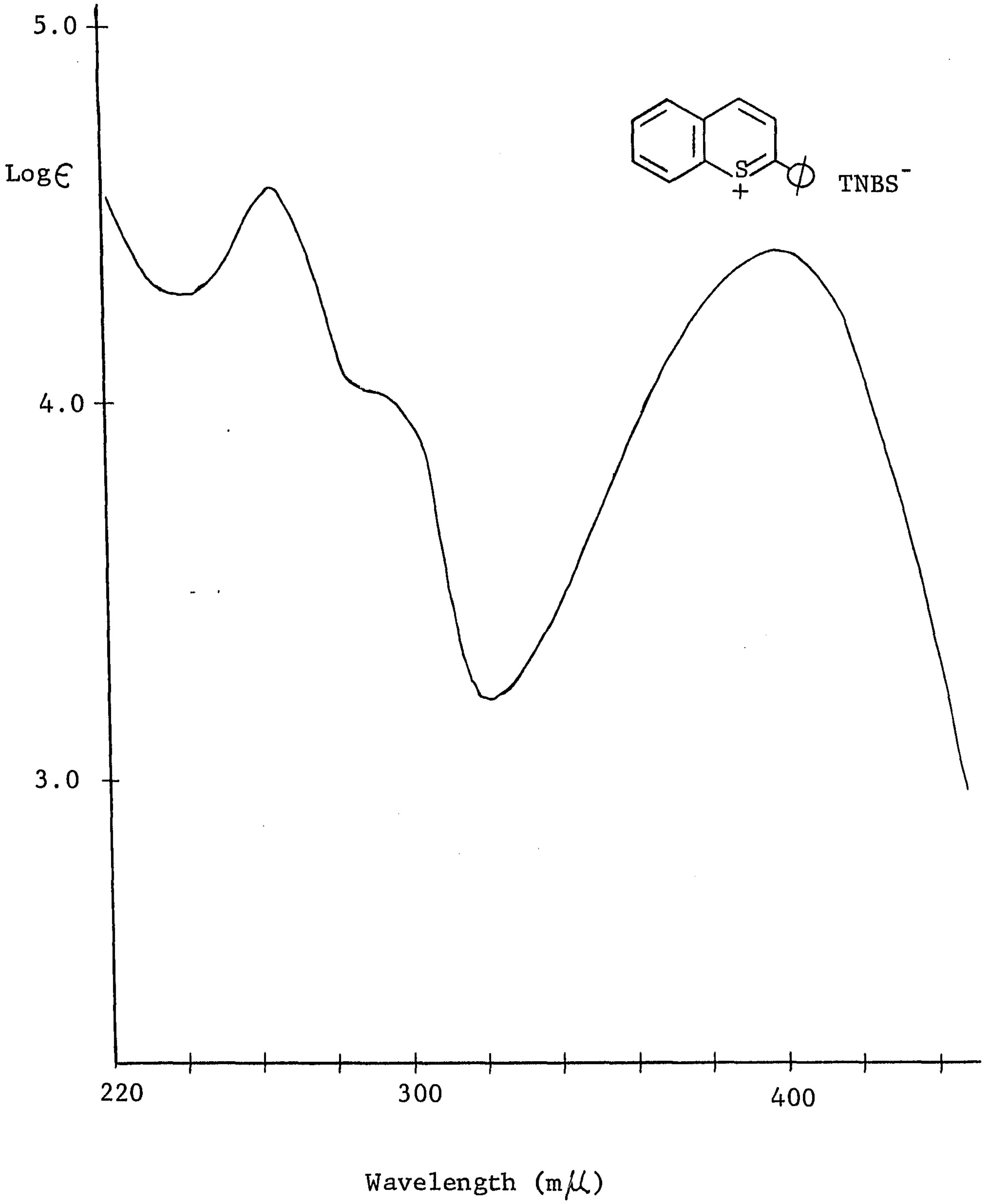
Since even very pure phenacyl bromide reacted with silver ion to give silver metal, benzyl bromide was selected as the potential alkylating agent or hydride ion abstractor in an effort to obviate the undesirable side reaction and to test this hypothesis. A yellow solid was obtained from the reaction which was carried out at -15°. On recrystallization from glacial acetic acid, the yellow material decomposed above 230° to a green-brown semi-solid which melted sharply at 240-241°. The yellow material analyzed for $C_{21}H_{13}N_3O_9S_2$ which is the molecular formula for 2-phenylthianaphthalenium 2,4,6-trinitrobenzenesulfonate (XXVII). Because of the insolubility of the yellow solid in everything except boiling glacial acetic acid, no nmr study could be done. Silver bromide was also obtained from the reaction.



In order to confirm the structure of compound XXVII, the compound was synthesized by an unambiguous route. Trityl salts of strong acids such as trityl perchlorate[32] and trityl tetrafluoroborate[33] have been used effectively as aromatizing reagents, presumably by hydride ion abstraction

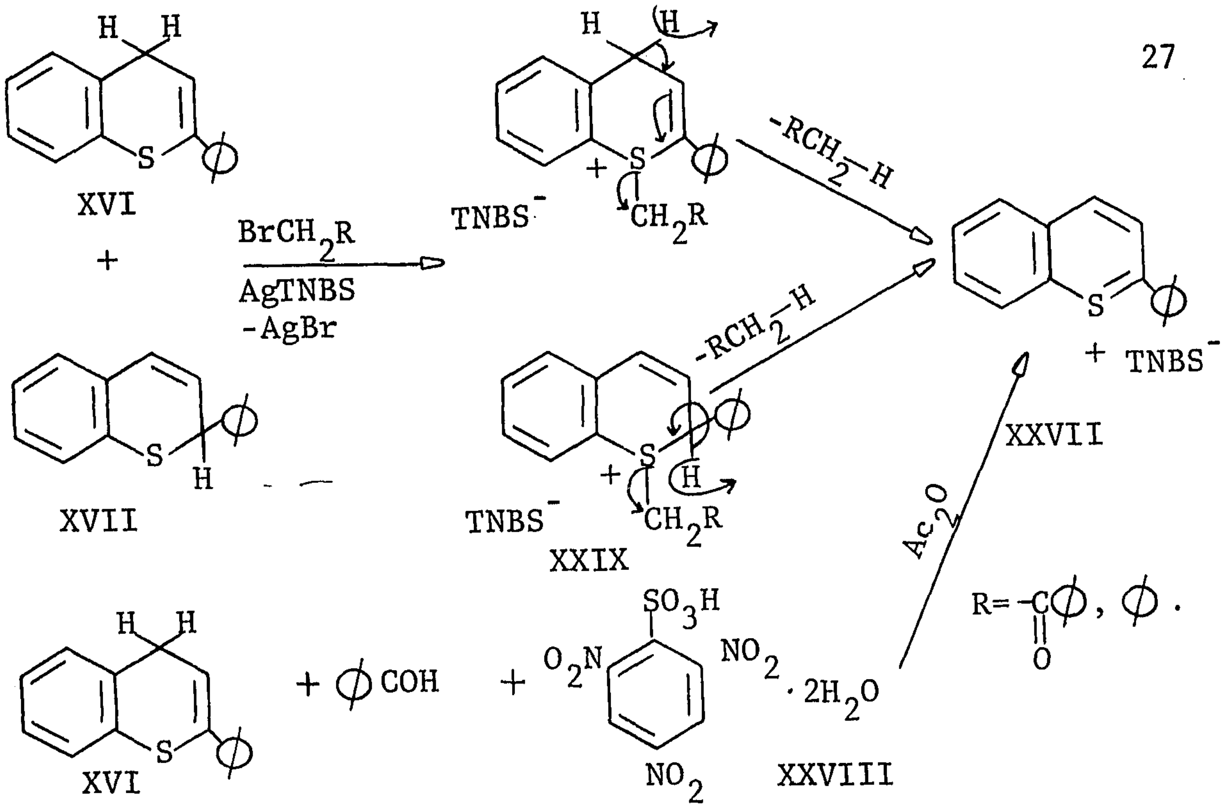
FIGURE 4

Ultraviolet-Visible Spectrum of 2-Phenyl-1-thianaphthalenium 2,4,6-Trinitrobenzenesulfonate



from the appropriate hydrocarbon.[34] As a result, trityl 2,4,6-trinitrobenzenesulfonate was prepared in situ from triphenylcarbinol and 2,4,6-trinitrobenzene sulfonic acid dihydrate (XXVIII) [31] in acetic anhydride. Addition of 2-phenyl-4H-(1)-benzothiapyran (XVI) to the acetic anhydride mixture resulted in the formation in high yield of a yellow solid with mp 247-248° dec. The analysis of the material was consistent with the expected product and the ultraviolet-visible spectra of the two compounds were identical in every respect (cf. Figure 4).

The experimental data suggests that (except for the diethylbromoacetal reaction where the main reaction occurred between silver ion and free bromoacetaldehyde to give only silver metal) the sulfonium salts (XXIX), generated initially from the reaction of compounds XVI and XVII with the appropriate alkylating agent in the presence of AgTNBS (XXVI), diproportionated to give the more stable thiapyrylium salt XXVII and the corresponding hydrocarbon resulting from the alkylating agent.

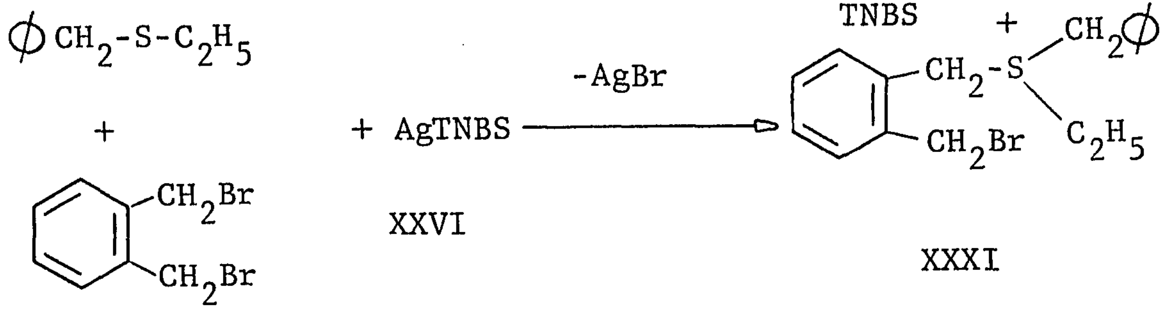


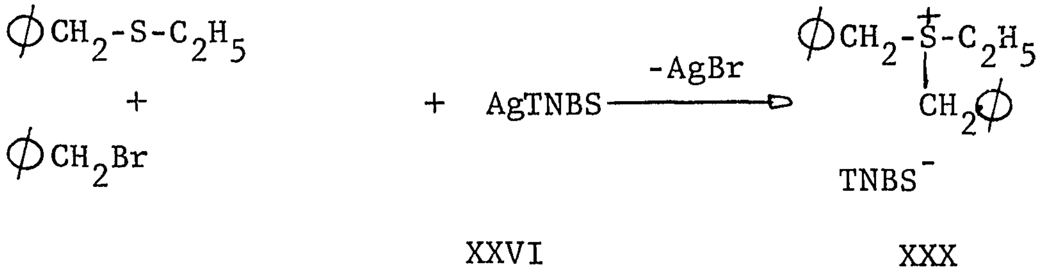
To obtain a better understanding of sulfonium salts in general, model compounds were prepared and evaluated. Ideas from three sources[31,35,36] were combined to realize the synthesis of the model compounds in good yield.

The method utilized a mixed solvent system of methylene chloride and nitromethane in the ratio of 2:3. The alkylating agent and the substrate in the molar ratio of 5:1 were dissolved in the mixed solvent system and a solution of the AgTNBS was added dropwise to the above solution. The silver bromide formed during the reaction was removed by filtration and then the sulfonium salt was precipitated with ether.

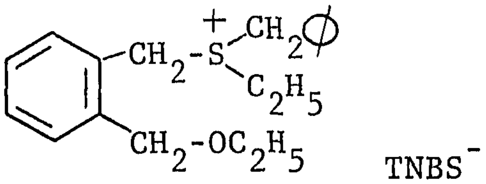
Dibenzylethylsulfonium 2,4,6-trinitrobenzenesulfonate (XXX) and benzyl-o-bromomethylbenzylethylsulfonium 2,4,6-

trinitrobenzenesulfonate XXXI were prepared in this manner.





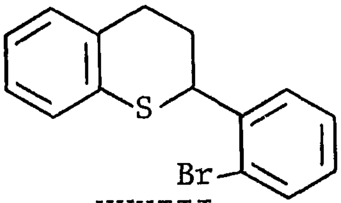
Both compounds were typically salt-like in solubility and each compound decomposed at its melting point. Because of the bromomethyl group in compound XXXI, the compound proved to be slightly lachrymatory and somewhat prone to solvolysis of the active halogen by hydroxylic solvents. Evidence for the facile solvolysis of the bromomethyl group was indicated by the fact that 15-20% of compound XXXI was converted to benzyl-o-ethoxymethylbenzylethylsulfonium 2,4,6-trinitrobenzenesulfonate (XXXII) on two recrystallizations from absolute ethanol-nitromethane.



XXXII

Microanalysis and nmr were used in the determination of the percentage of compound XXXII in compound XXXI.

The unexpected formation of thiapyrylium salt XXVII and the ease with which the model sulfonium salts XXX and XXXI were prepared indicated that a better intermediate for the thiachrysene skeleton would be 2-(2-bromophenyl) 1,2,3,4-tetrahydrobenzothiapyran (XXXIII).



XXXIII

The synthesis was begun with 2-bromotoluene which was oxidized with chromium trioxide in acetic anhydride and concentrated sulfuric acid[37] to give, after hydrolysis in aqueous sulfuric acid, 2-bromobenzaldehyde (XXXIV)[38] in fair yield. A Perkin reaction of XXXIV resulted in a good yield of 2-bromocinnamic acid (XXXV).[39] The method[20] used for the preparation of 3-phenylthio-3-phenylpropionic acid (XIV) as well as the method[40] used for the preparation of 3-phenylthiobutyric acid was tried in an unsuccessful attempt to synthesize 3-phenylthio-3-(2-bromophenyl) propionic acid (XXXVI). In general, only starting materials were recovered from the reaction mixtures (cf. p. 84 the Experimental Section).

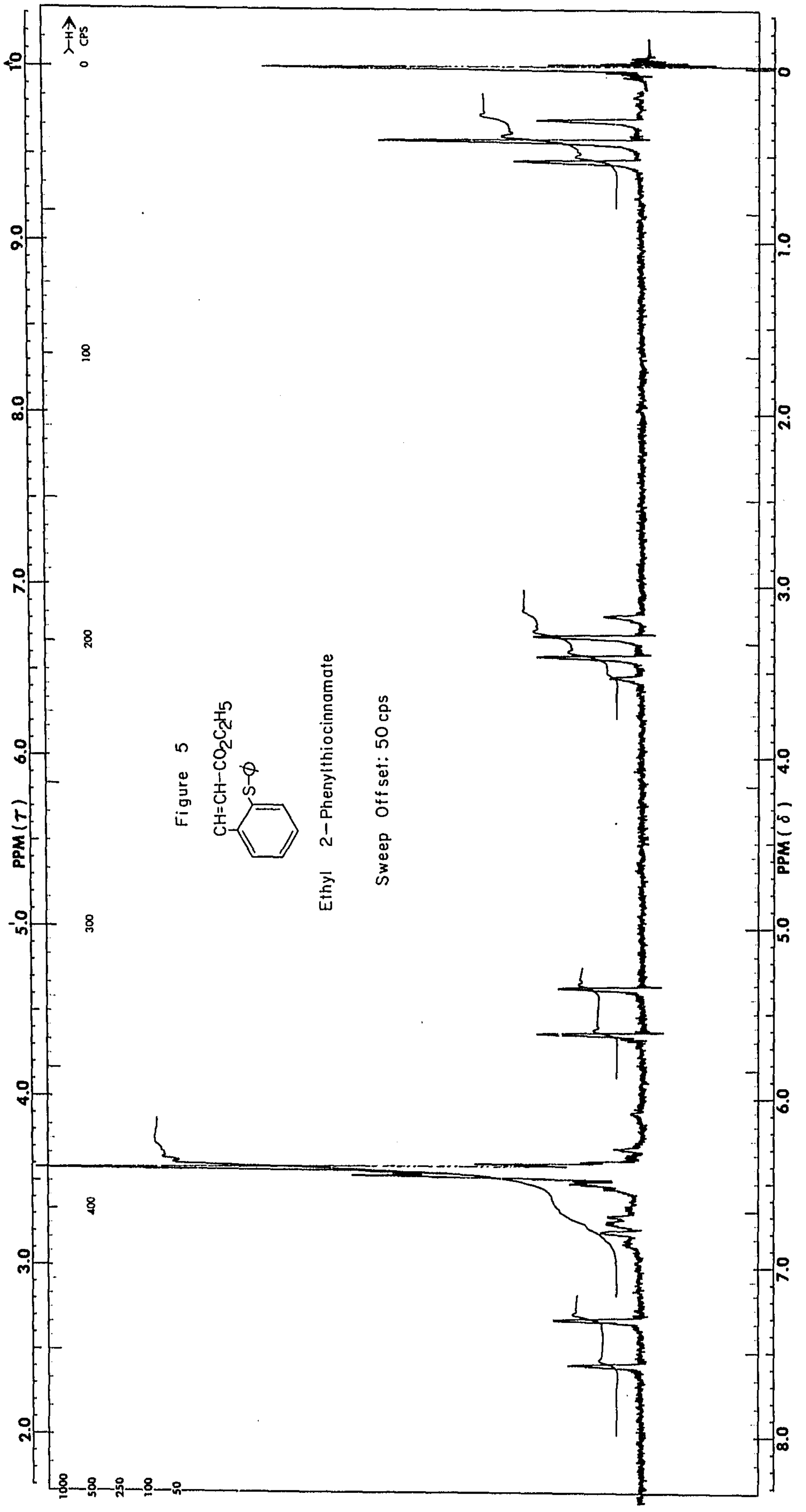
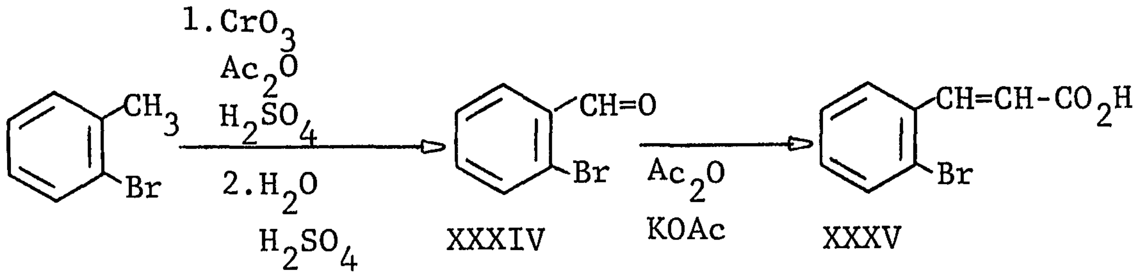
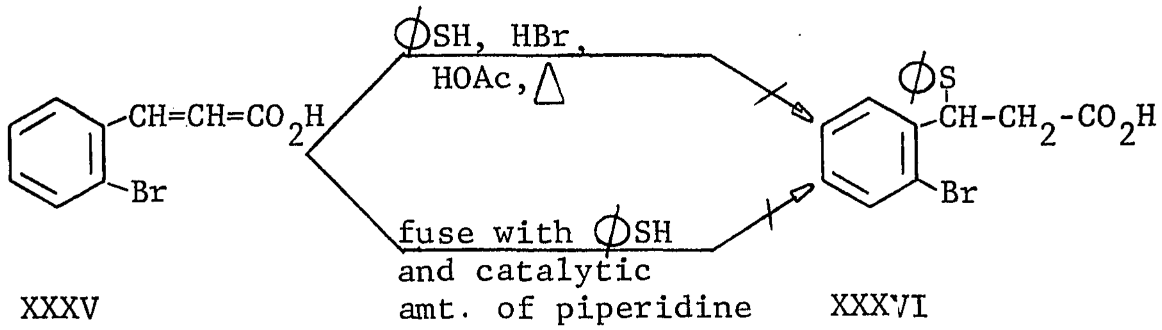


Figure 5

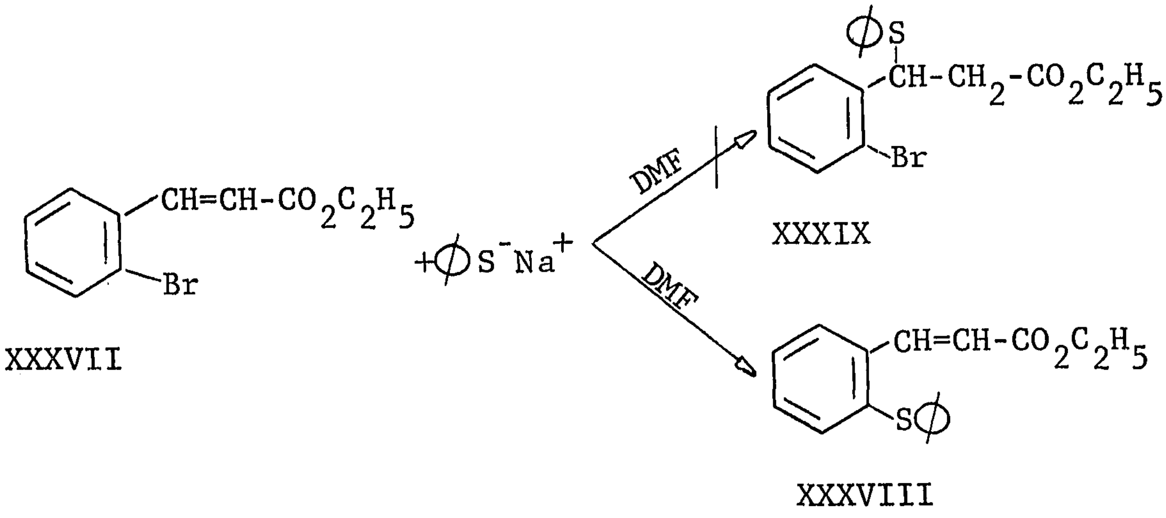
Ethyl 2–Phenylthiocinnamate

Sweep Offset: 50 cps

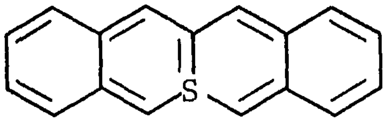




However, when ethyl 2-bromocinnamate (XXXVII)[41] was treated with sodium phenylthiolate in DMF, an interesting but unexpected reaction occurred in which the arylhalogen in compound XXXVII was displaced by phenylthiolate to give exclusively ethyl 2-phenylthiocinnamate (XXXVIII) instead of the desired product ethyl 3-phenylthio-3-(2-bromophenyl) propionate (XXXIX) (cf. Figure 5).

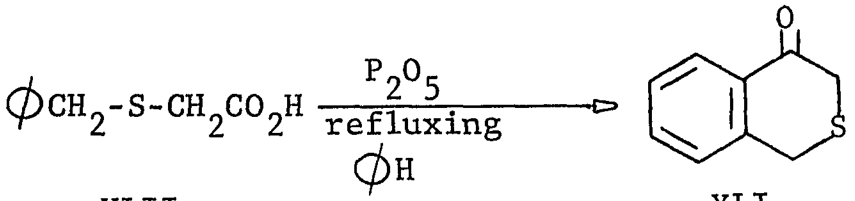


Since the thiachrysene skeleton could not be synthesized, preparation of thianaphthacene (XL) was attempted using isothiachromanone (XLI) as the precursor.



XL

Isothiachromanone (XLI) was prepared by a modification of a method used by Price[7] in which a benzene solution of S-benzylthioglycolic acid (XLII) was added to a gently refluxing slurry of phosphorus pentoxide in benzene. At best the yield of XLI was between 30-35%.



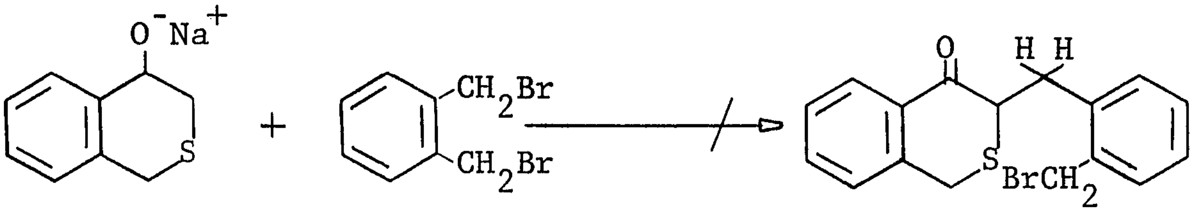
$$\phi CH_2\text{-}S\text{-}CH_2CO_2H \xrightarrow[\text{refluxing}\ \phi H]{P_2O_5}$$

XLII

XLI

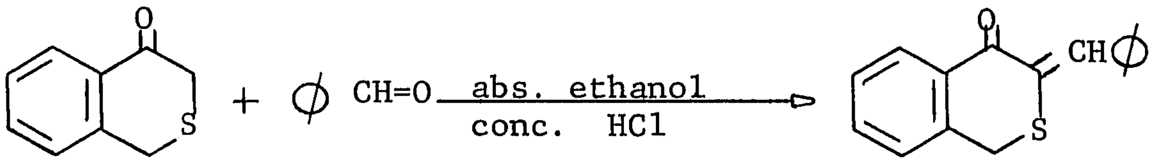
Attempts to C-alkylate the sodium enolate of isothiachromanone (XLI) using sodium hydride as the base and 1,2-dibromomethylbenzene (XLIII) as the alkylating agent were unsuccessful. Only starting materials and intractable resins were obtained.

XLI



XLIII

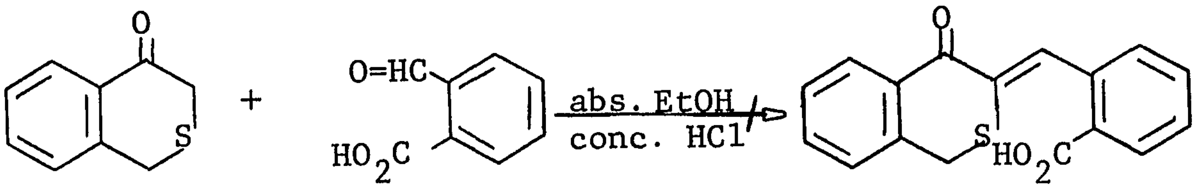
T E. Young[42] prepared 3-benzylideneisothiachromanone (XLIV) <u>via</u> the acid catalysed condensation of benzaldehyde with isothiachromanone (XLI).



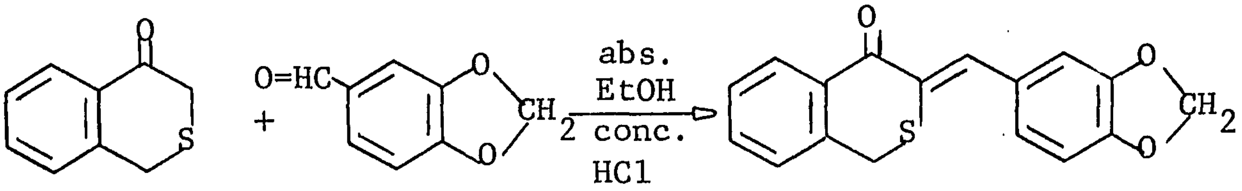
XLI

XLIV

In order to obtain the thianaphthacene skeleton, either an ortho substituted aldehyde or an appropriately substituted aldehyde which could be substituted subsequently in the ortho position would be required. An ortho substituted aldehyde, phthalaldehydic acid (XLV), was used but only tar was formed during the course of the reaction. Then an activated aldehyde, piperonal (XLVI) was used to give an 82% yield of the expected 3-piperonylideneisothiachromanone (XLVII).

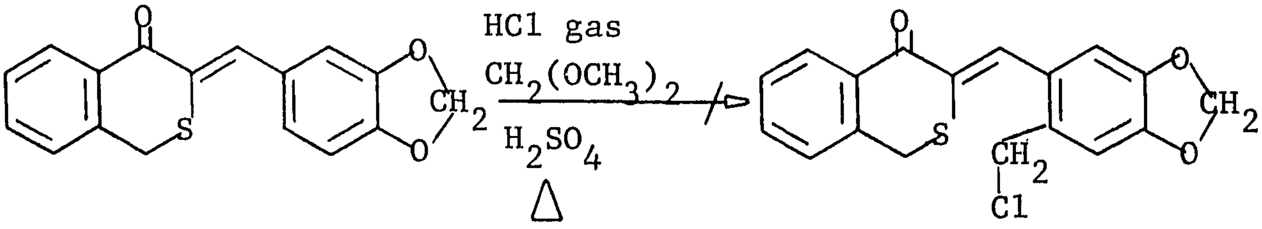


XLI XLV



XLI XLVI XLVII

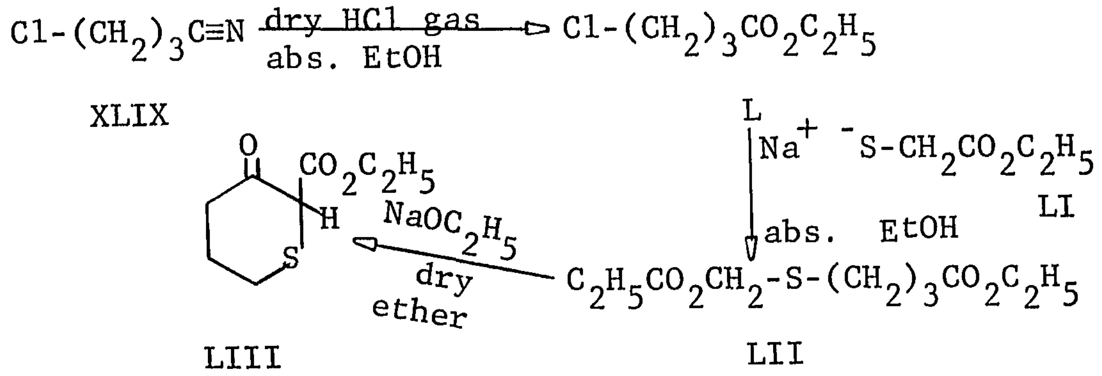
Ortho substitution on compound XLVII was attempted using an Organic Synthesis[43] method for the preparation of 2-hydroxy-5-nitrobenzyl chloride to effect the chloromethylation of compound XLVII. After compound XLVII was warmed for 3 hours with methylal, hydrogen chloride gas, and a catalytic amount of sulfuric acid, only unreacted starting material was recovered from the reaction.



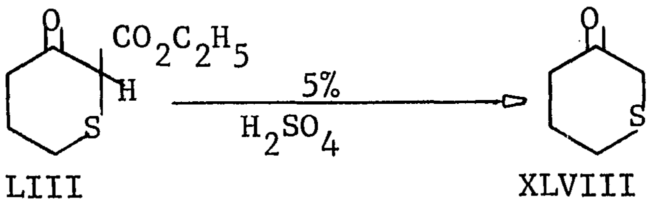
XLVII

Since the desired compounds were not produced, attempts to synthesize thianaphthalene (III) from tetrahydrothiapyran-3-one (XLVIII) were begun.

The synthesis of tetrahydrothiapyran-3-one (XLVIII) was accomplished in four steps[44] beginning with the acid catalyzed ethanolysis of 4-chlorobutyronitrile (XLIX) in absolute ethanol to give a good yield of ethyl 4-chlorobutyrate (L). Chloride ion was displaced from L with the sodium salt of ethyl thioglycolate (LI) to give a good yield of ethyl 4-(carbethoxymethylthio) butyrate (LII) which was cyclized under Dieckmann conditions (using freshly prepared, alcohol free sodium ethoxide) to give 2-carbethoxytetrahydrothiapyran-3-one (LIII) in about 60% yield.

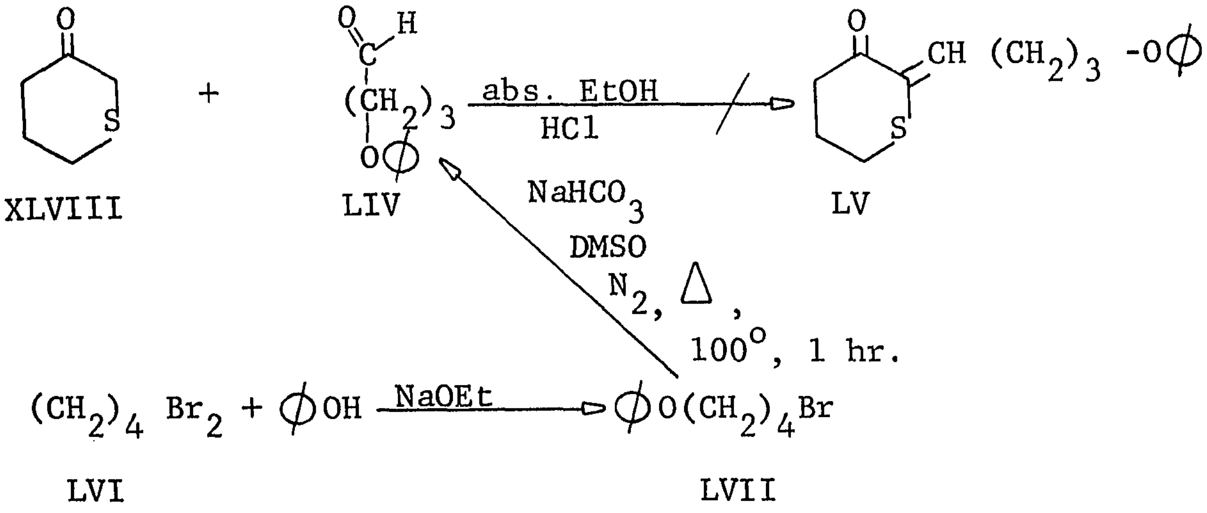


Ketoester LIII was warmed with 5% aqueous sulfuric acid for 5 hr to give, after careful neutralization with 10% sodium hydroxide solution and extraction, 64% yield of the desired tetrahydrothiapyran-3-one (XLVIII).



Ketone XLVIII, when treated with 4-phenoxybutyraldehyde (LIV) and hydrochloric acid in absolute ethanol, gave only tar and recovered starting materials instead of the expected

2-(4-phenoxybutyrylidene) tetrahydrothiapyran-3-one (LV). The 4-phenoxybutyraldehyde (LIV) was prepared by displacement of bromide on 1,4-dibromobutane (LVI) with sodium phenoxide to give 4-phenoxybutylbromide (LVII)[45] followed by oxidation of the remaining bromomethyl group to aldehyde LIV by dimethylsulfoxide (DMSO) and sodium bicarbonate at 100° for 1 hr under an inert atmosphere.[46]



When ketone XLVIII was treated with piperonal (XLVI) and hydrochloric acid in absolute ethanol, only 2,4-dipiperonylidenetetrahydrothiapyran-3-one (LVIII) was obtained instead of the expected 2-piperonylidenetetrahydrothiapyran-3-one (LIX). This result was confirmed by elemental analysis (cf. Experimental Section p.97).

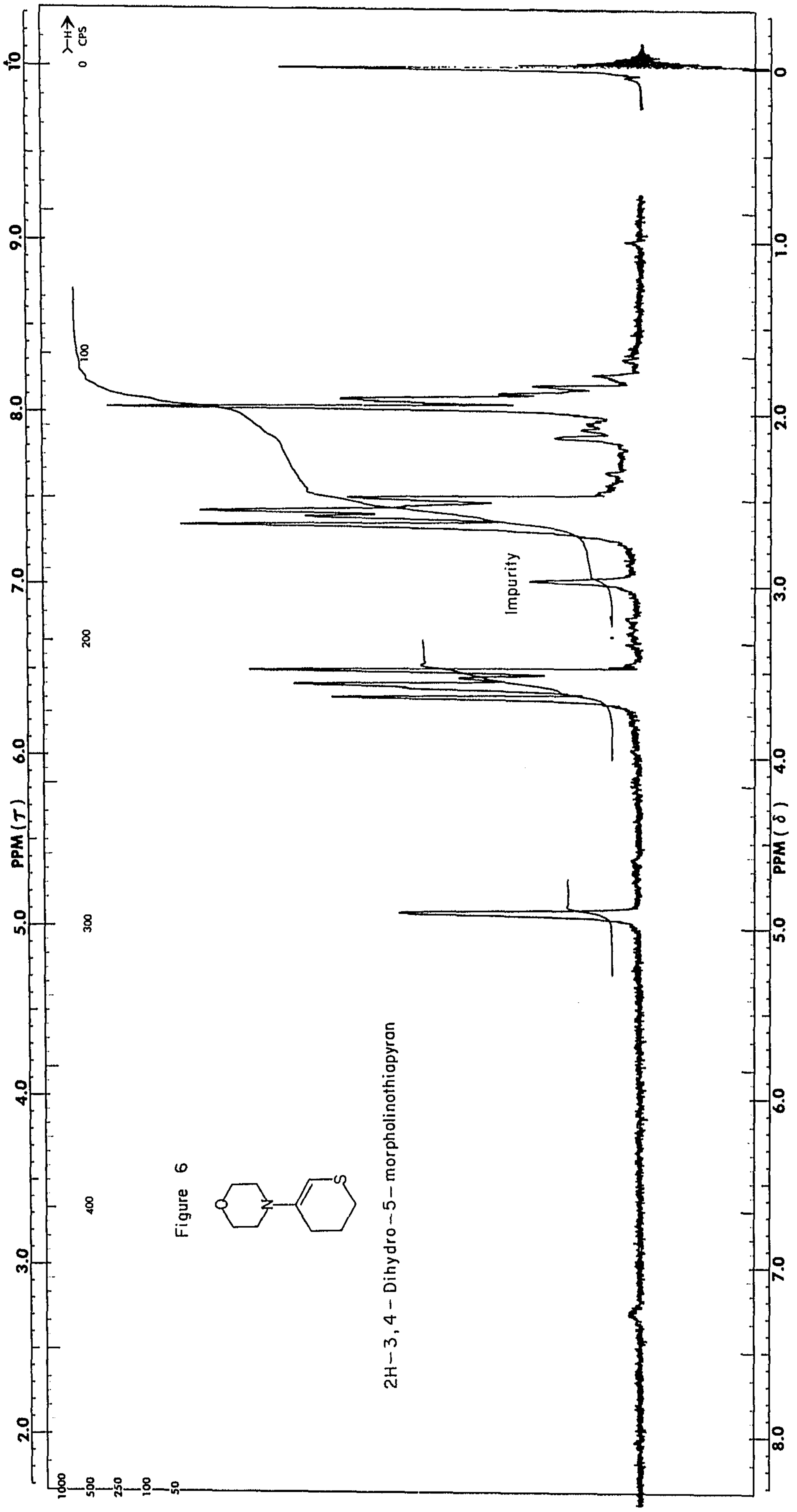
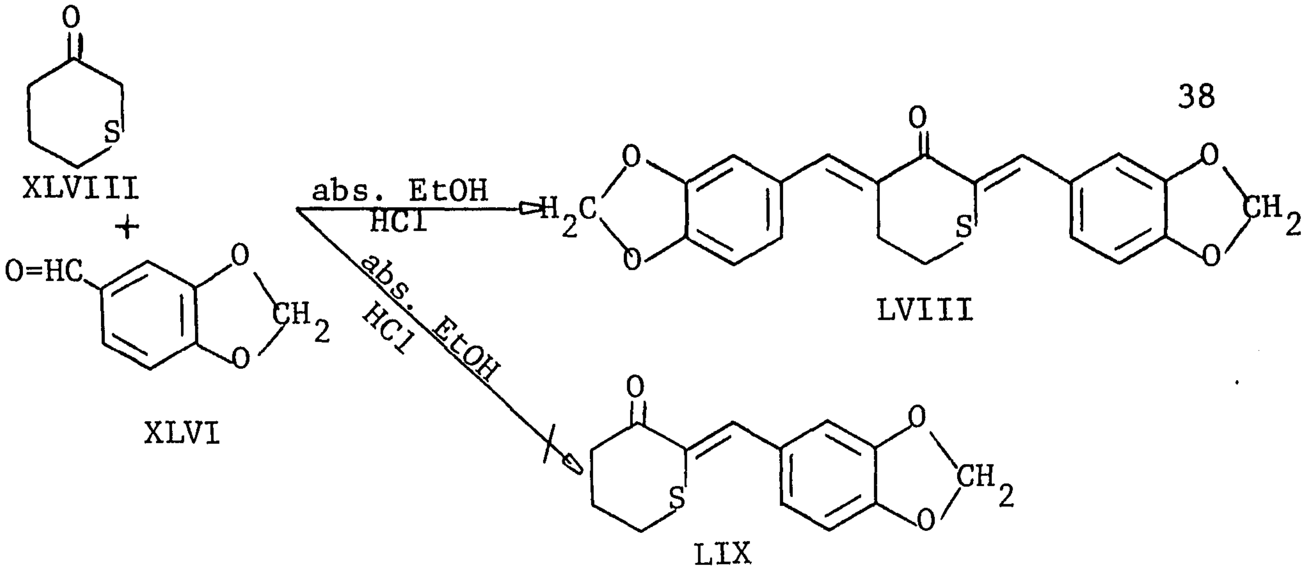
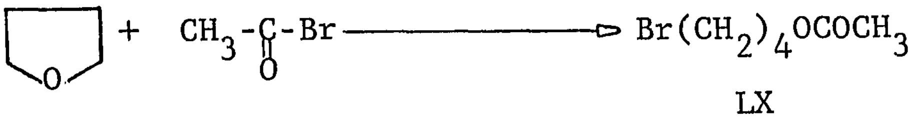


Figure 6

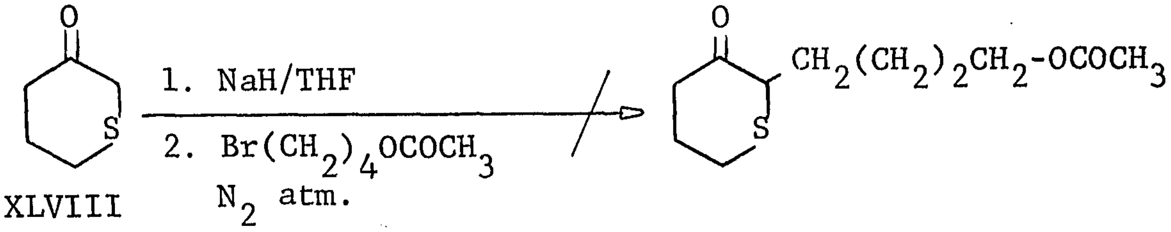
2H-3,4-Dihydro-5-morpholinothiapyran



An attempt was made to C-alkylate the sodium enolate of ketone XLVIII with a four-fold excess of 4-bromobutylacetate (LX) prepared from tetrahydrofuran and acetylbromide. Only an intractable tar and 3/4 of the original quantity of 4-bromobutylacetate (LX) was recovered.



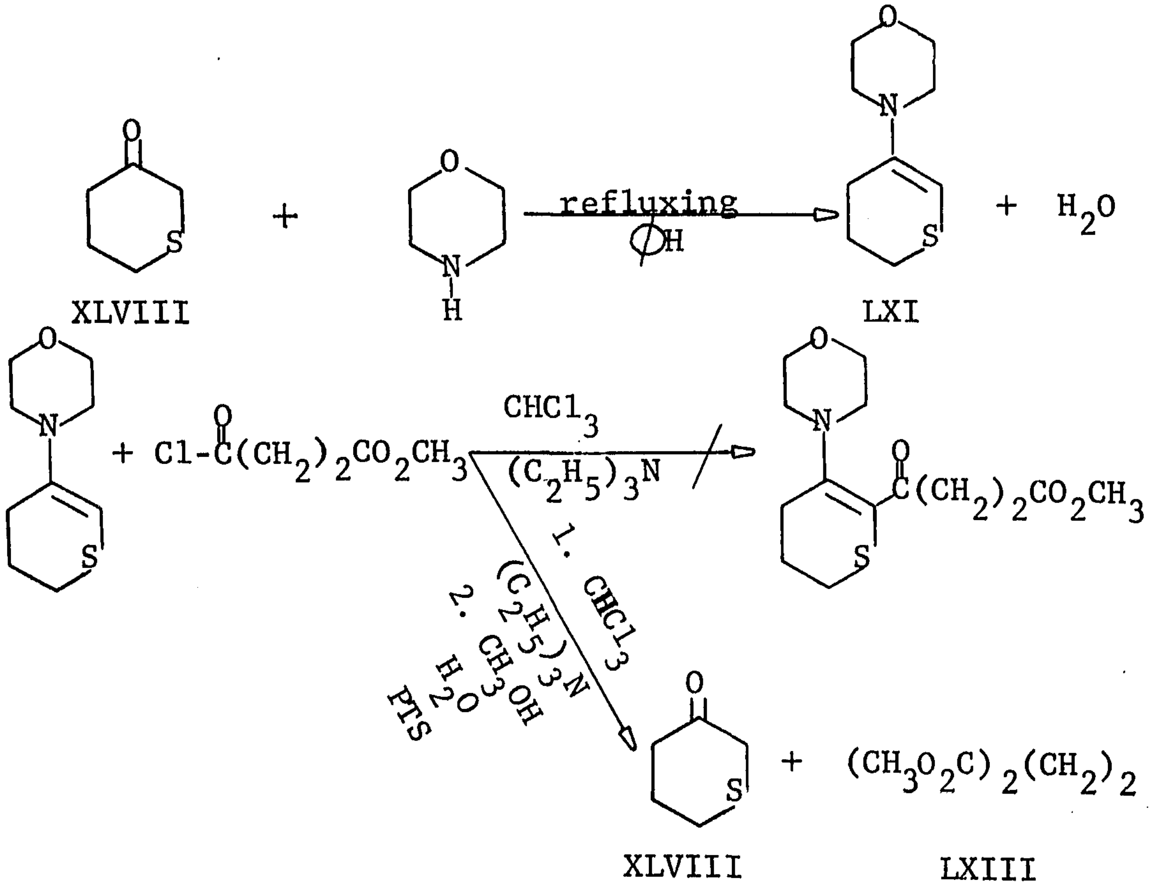
$CH_3-\underset{O}{\overset{\|}{C}}-Br \longrightarrow Br(CH_2)_4OCOCH_3$



The mopholine enamine LXI of ketone XLVIII was prepared in high yield by refluxing overnight a benzene solution of ketone LXVIII and a two-fold excess of morpholine and collecting the water formed in a Dean Stark trap. The nmr spectrum of the product obtained indicated that there was only one isomer, 2H-3,4-dihydro-5-morpholinothiapyran

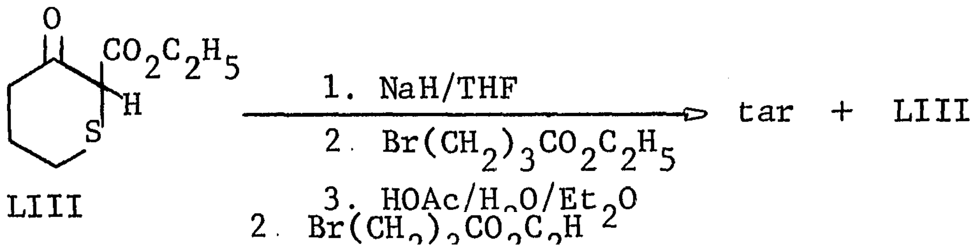
(LXI) (cf. Figure 6). The experiment was repeated and again only one isomer was obtained.

Attempted acylation of enamine LXI with 3-carbomethoxypropionyl chloride (LXII)[47] in dry chloroform gave only a mixture of tetrahydrothiapyran-3-one (XLVIII) and dimethylsuccinate (LXIII). Compounds XLVII and LXIII are products generated during the work-up of the reaction mixture by hydrolysis of enamine LXI and acid chloride LXII.



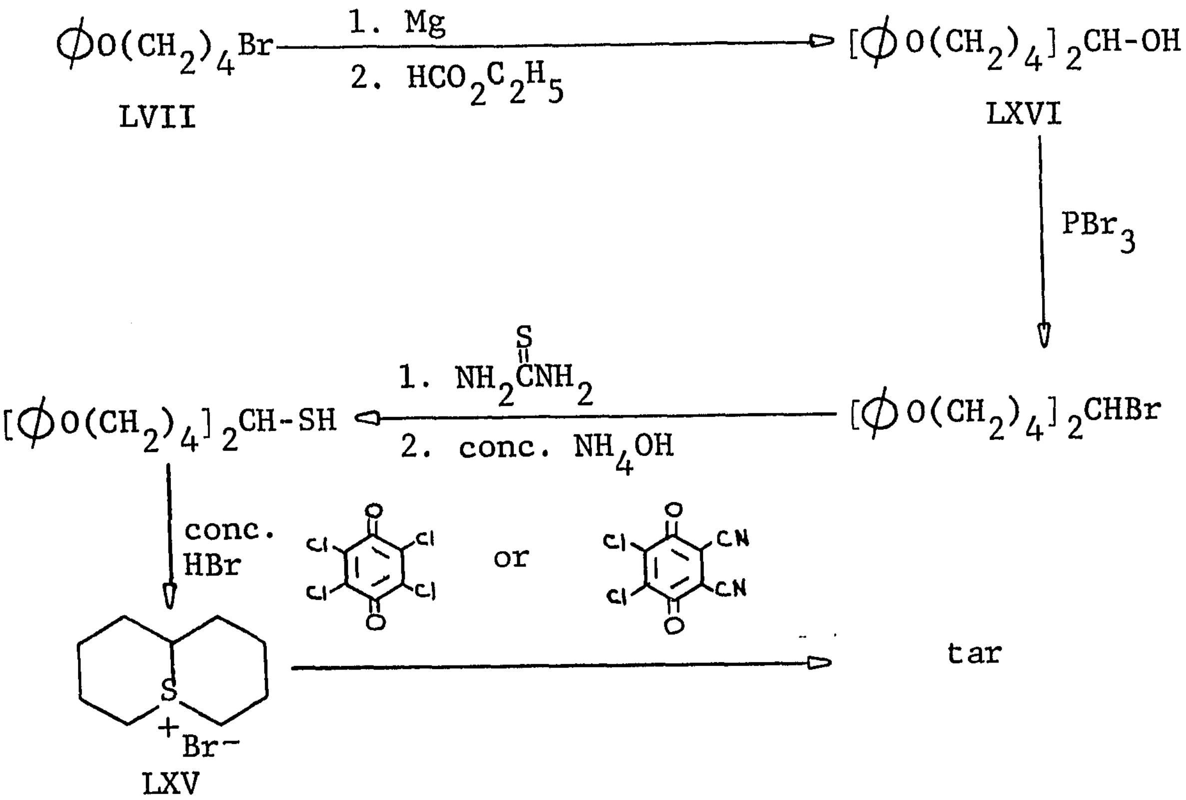
Since tetrahydrothiapyran-3-one (XLVIII) proved to be an unsatisfactory precursor for 4a-thianaphthalene (III), ketoester LIII was next considered.

Treatment of the sodium enolate (prepared by the addition of ketoester LIII to a sodium hydride slurry) of compound LIII with ethyl 4-bromobutyrate (LXIV) resulted in considerable tar formation and recovery of unreacted ketoester.



Eastman and Kritchevsky[48] developed a synthetic route to bicyclic sulfonium salts with sulfur at a bridgehead using acyclic intermediates. Bicyclo [4.4.0] decane-1-thianium bromide (LXV) was prepared in five steps beginning with the action of 2 mols of 4-phenoxybutylmagnesium bromide on ethyl formate to give 1,9-diphenoxy-5-nonanol (LXVI) which was converted to 1,9-diphenoxy-5-bromononane (LXVII) with phosphorous tribromide in carbon disulfide. Conversion of LXVII to 1,9-diphenoxy-5-nonanethiol (LXVIII)[42] was accomplished by the action of thiourea on LXVII followed by hydrolysis to thiol (LXVIII). Hydrolysis of thiol

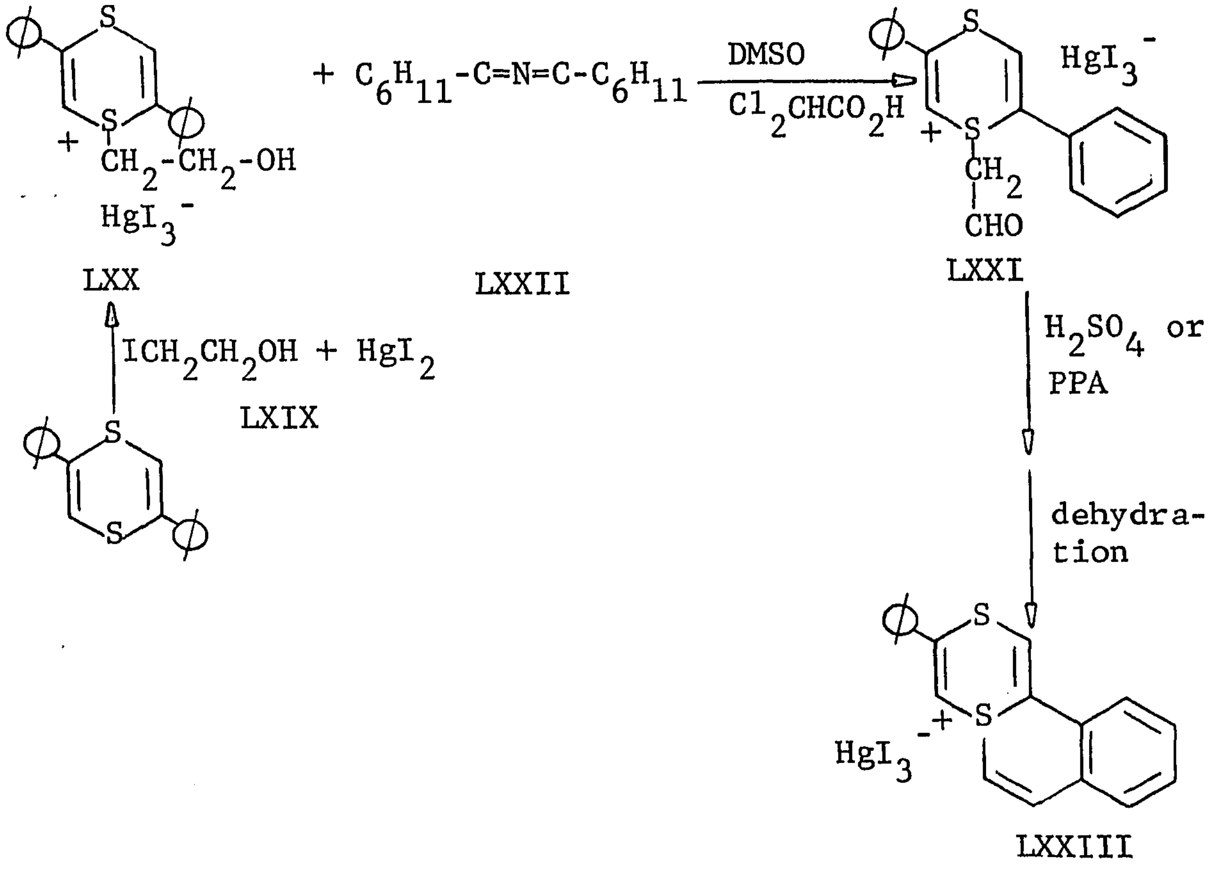
LXVIII in concentrated hydrobromic acid converted LXVIII to the desired sulfonium salt LXV.[42] However, attempted dehydrogenation[42] of sulfonium salt LXV with chloranil or dichlorodicyanobenzoquinone was unsuccessful, for only tar was formed.



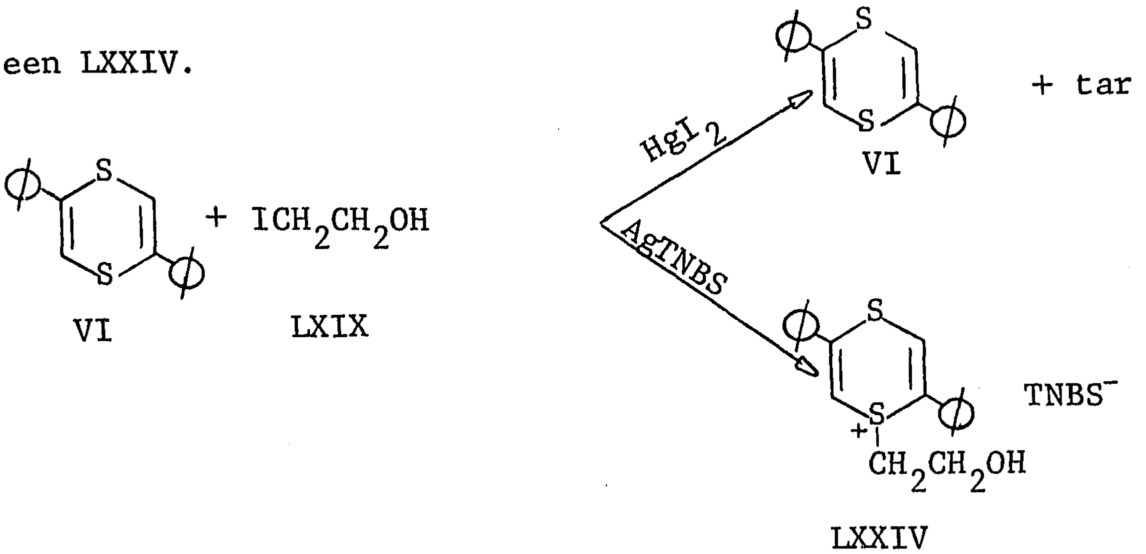
Synthesis and Reactions of 1-Alkyl-2,5-Diphenyl-1,4-Dithiinium Salts.

Because of the problems encountered with all of the previously described precursors, a totally new approach was devised using 2,5-diphenyl-1,4-dithiin (VI)[12] as the precursor. It was intended that VI could be alkylated with iodoethanol (LXIX) and mercuric iodide[36] to give 1-(2-

hydroxyethyl) 2,5-diphenyl-1,4-dithiinium triiodomercurate (LXX). Alcohol LXX was to be converted to the corresponding aldehyde LXXI by means of a method developed by Moffatt[49,50,51] for the mild oxidation of alcohols to aldehydes, in which the oxidation was effected by dimethylsulfoxide and dicyclohexylcarbodiimide (LXXII) in the presence of a proton source (Cl_2CHCO_2H). Aldehyde LXXXI was to be ring closed in acid onto one of the benz rings, and then dehydrated to give compound LXXIII which has a sulfur atom located at a bridgehead and a potential donor atom (sulfur) in conjugation with the sulfonium center.

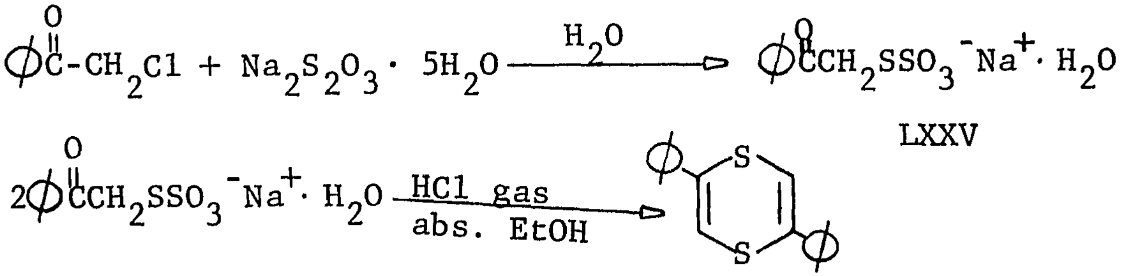


When compound VI was treated with iodoethanol (LXIX) and mercuric iodide, only compound VI along with tar was recovered from the reaction. The mercuric iodide was replaced by AgTNBS (XXVI) and the method[31,35,36] developed for model sulfonium salts XXX and XXXI was used in an effort to prepare 1-(2-hydroxyethyl)2,5-diphenyl-1,4-dithiinium 2,4,6-trinitrobenzesulfonate (LXXIV). When the reaction was run, silver iodide formed and, on addition of ether to the filtrate after the silver iodide had been removed, a sticky brown material, which decomposed quickly on standing, was obtained. The ether insoluble material could well have been LXXIV.



Then VI was treated with a series of alkylating agents, such as phenacyl chloride, benzyl bromide, or isopropyl iodide in the presence of AgTNBS to determine whether or not VI could be alkylated. In every case, silver halide was formed and a very unstable solid was precipitated from the filtrate with ether. Because of these inconclusive results, it was decided that the alkylation of VI be studied in detail.

Sodium phenacylthiosulfate monohydrate (LXXV),[12] prepared from phenacyl chloride and sodium thiosulfate pentahydrate, underwent condensation followed by dehydration in acid to give 2,5-diphenyl-1,4-dithiin (VI)[12] in fair yield. The amount of acid used to effect the reaction was important, for if too little acid was used a material which resulted from the interaction of 3 mols of LXXV was formed, but if too much acid was used dithiin VI suffers extensive polymerization. In order to obtain pure product, the crude material obtained on filtration of the reaction mixture was first recrystallized from glacial acetic acid and then absolute ethanol.



$$\phi\overset{O}{\overset{\|}{C}}\text{-}CH_2Cl + Na_2S_2O_3\cdot 5H_2O \xrightarrow{H_2O} \phi\overset{O}{\overset{\|}{C}}CH_2SSO_3^-Na^+\cdot H_2O$$

LXXV

$$2\phi\overset{O}{\overset{\|}{C}}CH_2SSO_3^-Na^+\cdot H_2O \xrightarrow[\text{abs. EtOH}]{\text{HCl gas}}$$

LXXV

VI

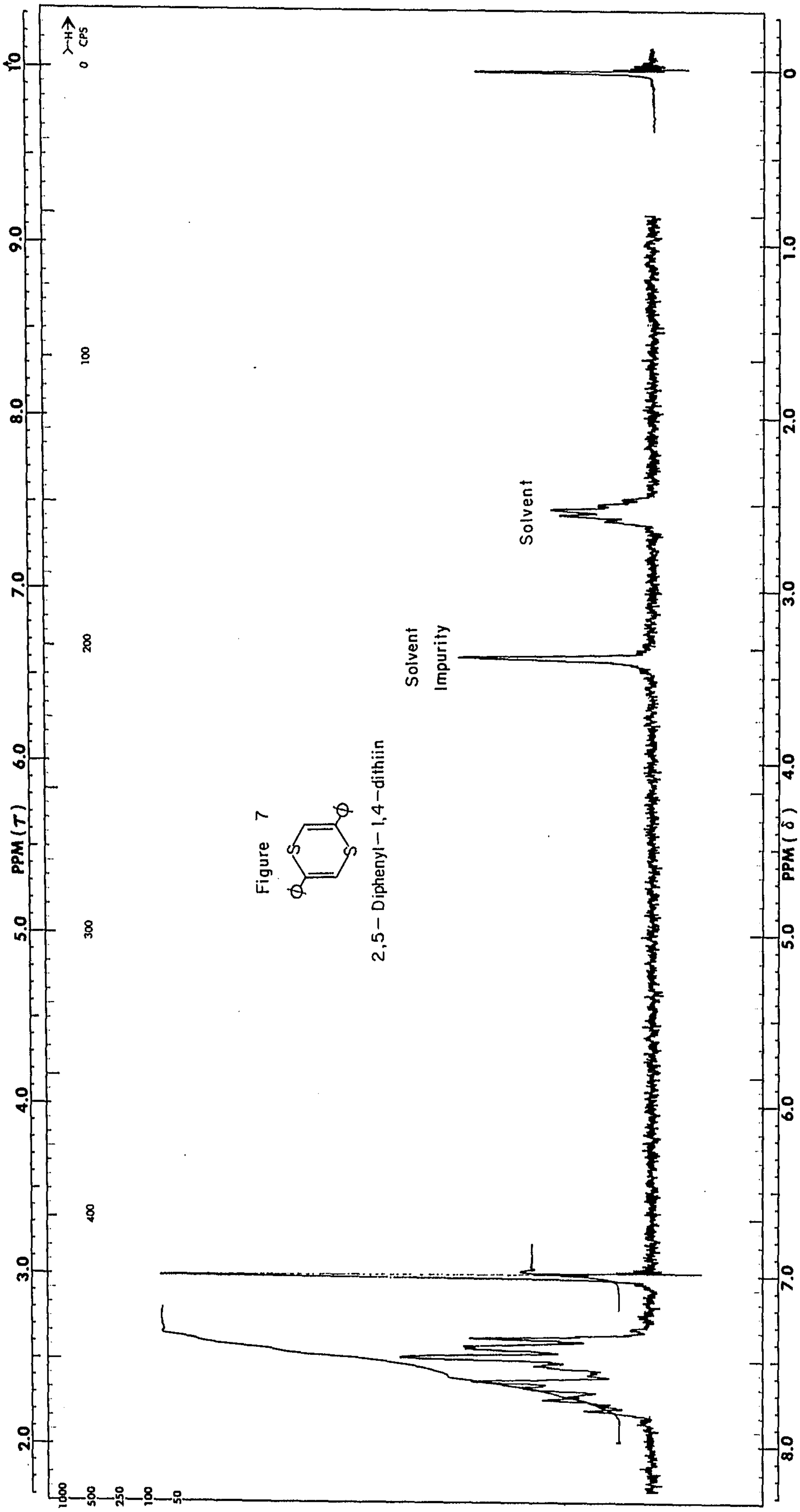


Figure 7

2,5-Diphenyl-1,4-dithiin

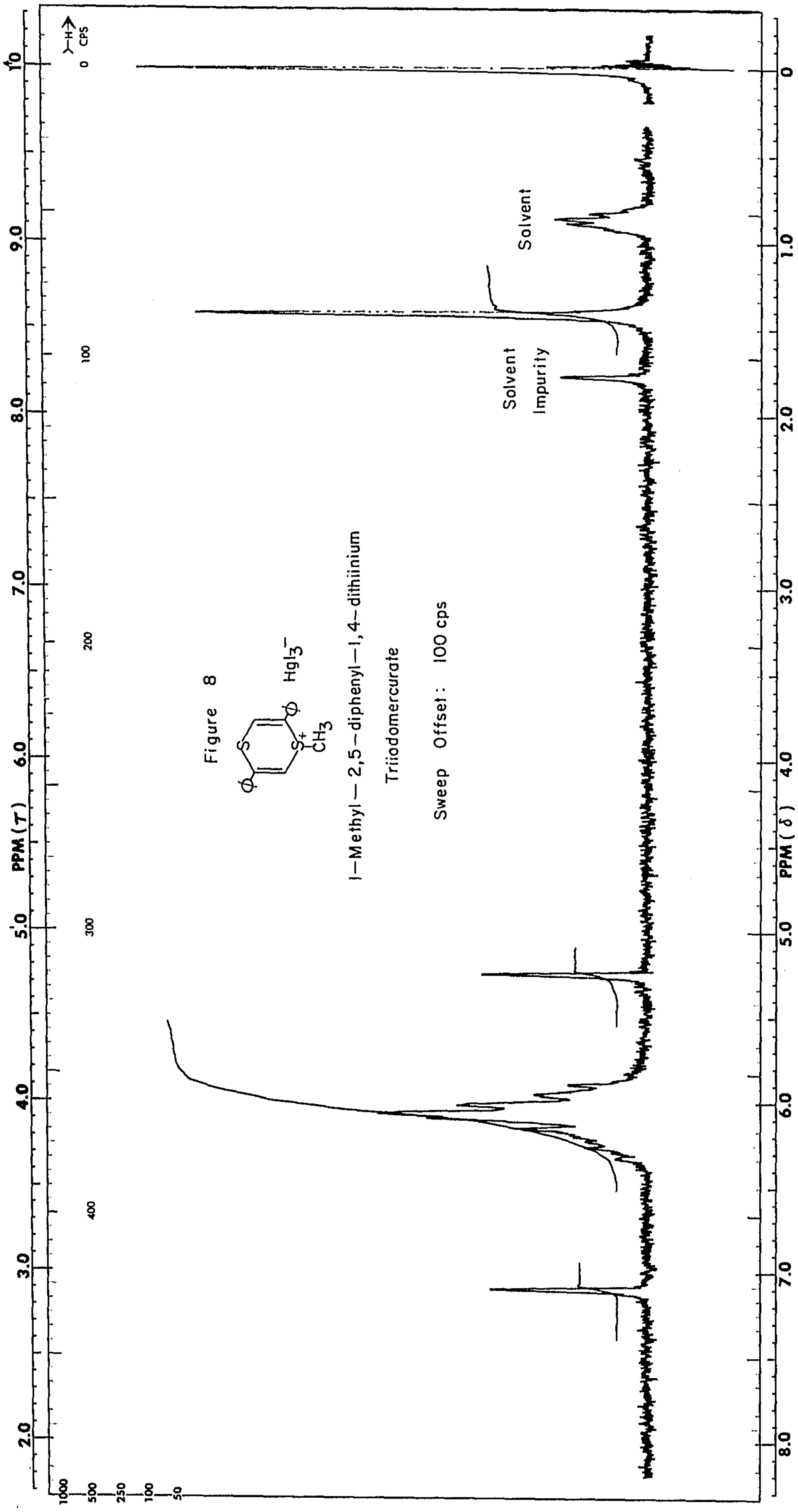


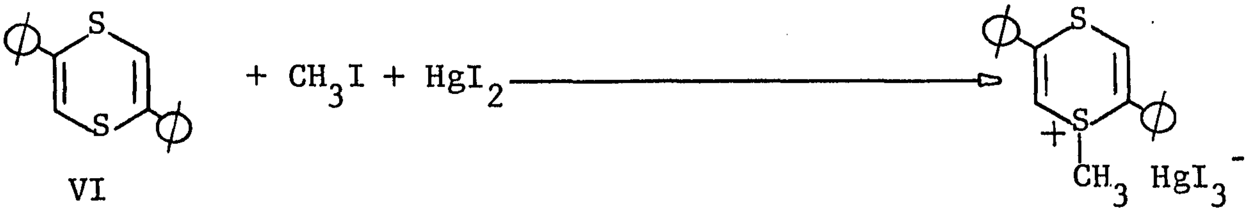
Figure 8

1-Methyl—2,5-diphenyl-1,4-dithiinium

Triiodomercurate

Sweep Offset: 100 cps

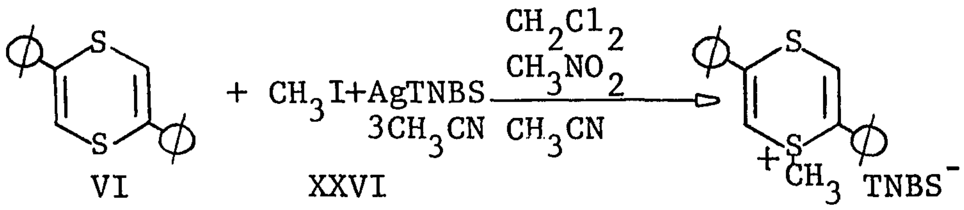
Alkylation of VI was attempted using methyl iodide and mercuric iodide[36] to give a yellow, ether insoluble product. Comparison of the nmr spectrum of VI with the nmr spectrum of the yellow solid showed that the two equivalent vinyl protons of dithiin VI were now significantly nonequivalent in the yellow solid. One of the vinyl protons shifted downfield more than 100 cps while the other vinyl proton showed a slight upfield shift (cf. Figures 7 and 8). Elemental analysis of the compound was consistent with the proposed structure (LXXVI) for the yellow solid. Because



LXXVI

1-methyl-2,5-diphenyl-1,4-dithiinium triiodomercurate resinified quickly in ambient conditions and because the triiodomercurate ion was found to be unstable in acid medium, a modification of Pettitt's method[31] was developed using an acetonitrile solvate of silver 2,4,6-trinitrobenzenesulfonate (XXVI)[31] silver perchlorate (LXXVII) or silver tetrafluoroborate (LXXVIII).

Silver 2,4,6-trinitrobenzenesulfonate (XXVI),[31] shown by elemental analysis to have 3 mols of acetonitrile associated with each mol of silver salt, was used successfully in the alkylation of VI with methyl iodide.



VI XXVI LXXIX

However, if commercial silver perchlorate or silver tetrafluoroborate were substituted for AgTNBS (XXVI), only silver iodide formed and VI was recovered. It was found that when the commercial silver salts were treated with warm acetonitrile and then precipitated with ether, new silver salts containing 4 mols of acetonitrile per mol of silver salt resulted. The new silver salts LXXVII and LXXVIII were far less hygroscopic and much less sensitive to light than were the nonsolvated salts. It was found that if silver nitrate and either anhydrous sodium perchlorate or anhydrous sodium tetralfuoroborate were dissolved in acetonitrile and allowed to stir for a while, sodium nitrate precipitated to give an acetonitrile solution of the respective silver salts. After removal of the sodium nitrate precipitate, solvates LXXVII and LXXVIII were precipitated in high purity and good yield with ether.

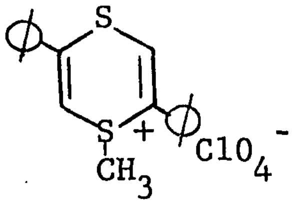
$$AgNO_3 + NaClO_4 \xrightarrow[2.Et_2O]{1.CH_3CN} NaNO_3 + \underset{\text{LXXVII}}{AgClO_4 \cdot 4CH_3CN}$$

$$AgNO_3 + NaBF_4 \xrightarrow[2.\ Et_2O]{1.\ CH_3CN} NaNO_3 + AgBF_4\cdot 4CH_3CN$$

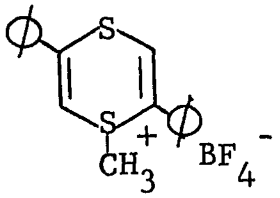
LXXVIII

Both salts were found to be effective in the preparation of 1-alkyl-2,5-diphenyl-1,4-dithiinium salts.

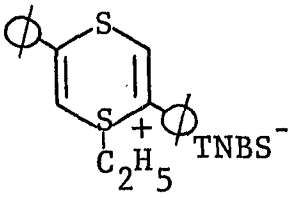
Using methyl iodide or ethyl iodide and one of the silver salts (XXVI, LXXVII, or LXXVIII) with dithiin VI, a series of 1-alkyl-2,5-diphenyl-1,4-dithiinium salts was prepared.



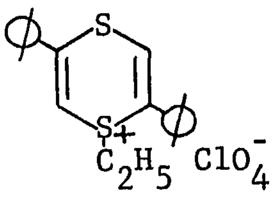
LXXX



LXXXI



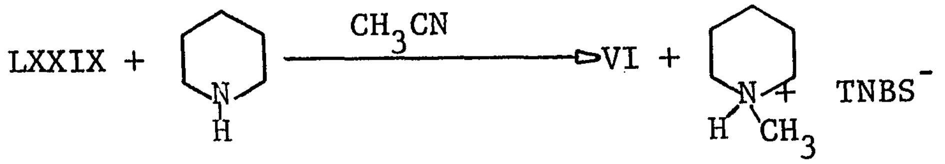
LXXXII



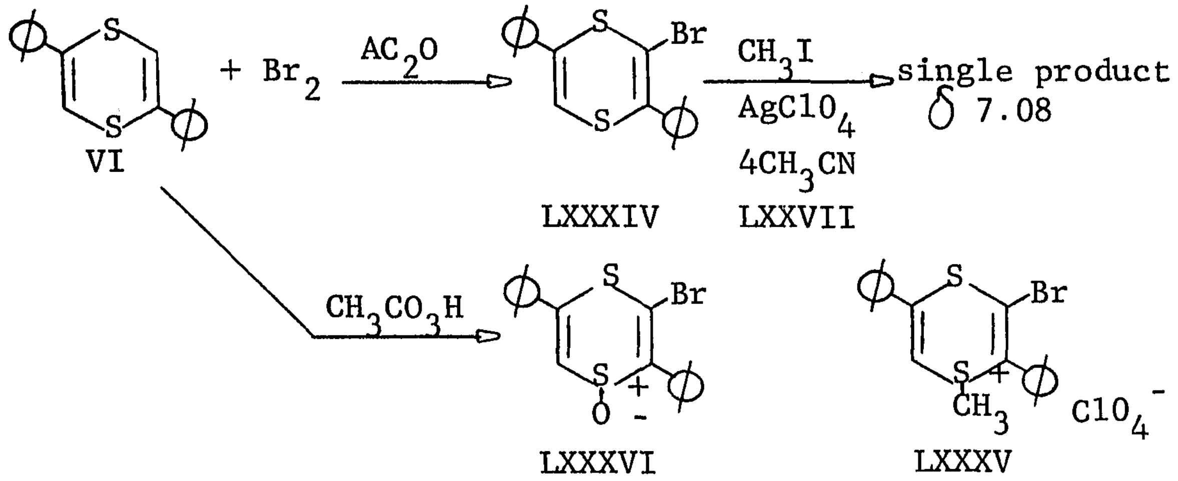
LXXXIII

Salts LXXIX to LXXXIII were white crystalline solids which were stable in acid solution unlike dithiin VI. Salts LXXIX and LXXXII were light sensitive and as a result deteriorate slowly if exposed even for short periods of time. In addition, the salts, e.g. LXXXI and LXXIX, reacted with nucleophiles such as dimethyl sulfide, piperidine, thioanisole, ethoxide, hydroxide, water, iodide and bromide to give dithiin VI and a transalkylated product which was isolated for the first two nucleophiles mentioned.

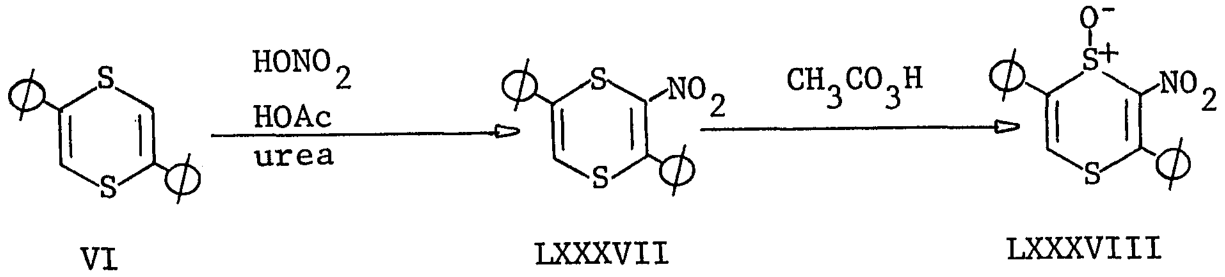
$$\text{LXXXI} + (CH_3)_2S \xrightarrow{CH_3CN} \text{VI} + (CH_3)_3S^+ \; BF_4^-$$



In order to determine whether H-3 or H-6 in the dithiinium salts was shifted far downfield in the nmr spectrum a monosubstituted derivative, 3-bromo-2,5-diphenyl-1,4-dithiin (LXXXIV)[52] was prepared by direct bromination of dithiin VI in acetic anhydride. Compound LXXXIV was treated with silver perchlorate (LXXVII) and methyl iodide to give a single product which has only one olefinic proton showing in the nmr spectrum. The proton appears (δ 7.08) on the upfield side of the phenyl resonance. Since Szmant and Alfonso[53] prepared monosulfoxide LXXXVI from bromodithiin LXXXIV, it may be concluded that alkylation occurred at the same site and that the resonance at δ 7.08 probably belonged to H-6 in 1-methyl-3-bromo-2,5-diphenyl-1,4-dithiinium perchlorate (LXXXV).

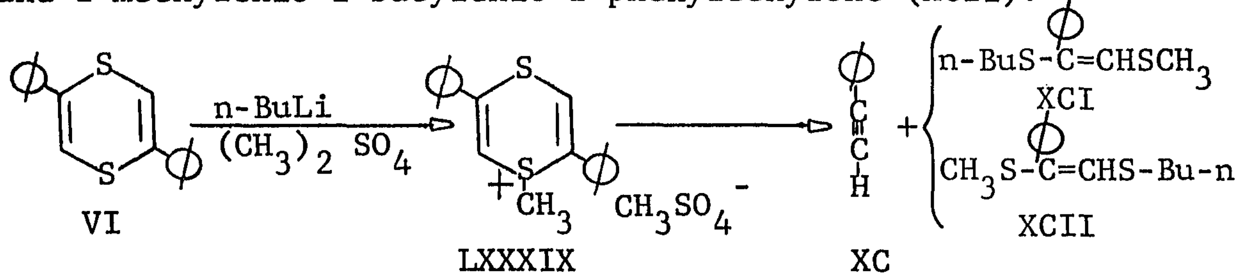


Parham[54] prepared 3-nitro-2,5-diphenyl-1,4-dithiin (LXXXVII) by direct nitration of dithiin VI in acetic anhydride using a 10M nitrating solution. Szmant and Alfonso[53] prepared the monosulfoxide of LXXXVII and assigned structure LXXXVIII to the yellow compound.



Treatment of LXXXVII with methyl iodide and AgTNBS (XXVI) gave a yellow compound which was too unstable to isolate. No nmr spectrum could be obtained to see whether there was a downfield proton in the nmr spectrum as would be expected on the basis of the tentative assignment for salt LXXXV.

Parham[55] found that dithiin VI did not react with n-butyllithium except in the presence of excess dimethyl sulfate. A 1-methyl-1,4-dithiinium salt LXXXIX was postulated as the intermediate in the ring cleavage of LXXXIX to give phenylacetylene (XC) and possibly two other products, 1-butylthio-2-methylthio-1-phenylethylene (XCI) and 1-methylthio-2-butylthio-1-phenylethylene (XCII).



When 1-methyl-2,5-diphenyl-1,4-dithiinium tetrafluoroborate (LXXXI) was treated with excess n-butyllithium at -20°, a noticeable reaction began at -10° to give 44% yield of dithiin VI resulting from demethylation of salt LXXXI by attack of the n-butyl carbanion on the methyl group. In addition, a 42% yield of phenylacetylene (XC) and a 44% yield of a material which was shown to be a mixture of cis-and trans-1-butylthio-2-methylthio-1-phenylethylene (XCI) was obtained. The structure of XCI was established by comparison with a genuine sample of XCI prepared in an unambiguous way from the reaction of methyl phenacyl sulfide

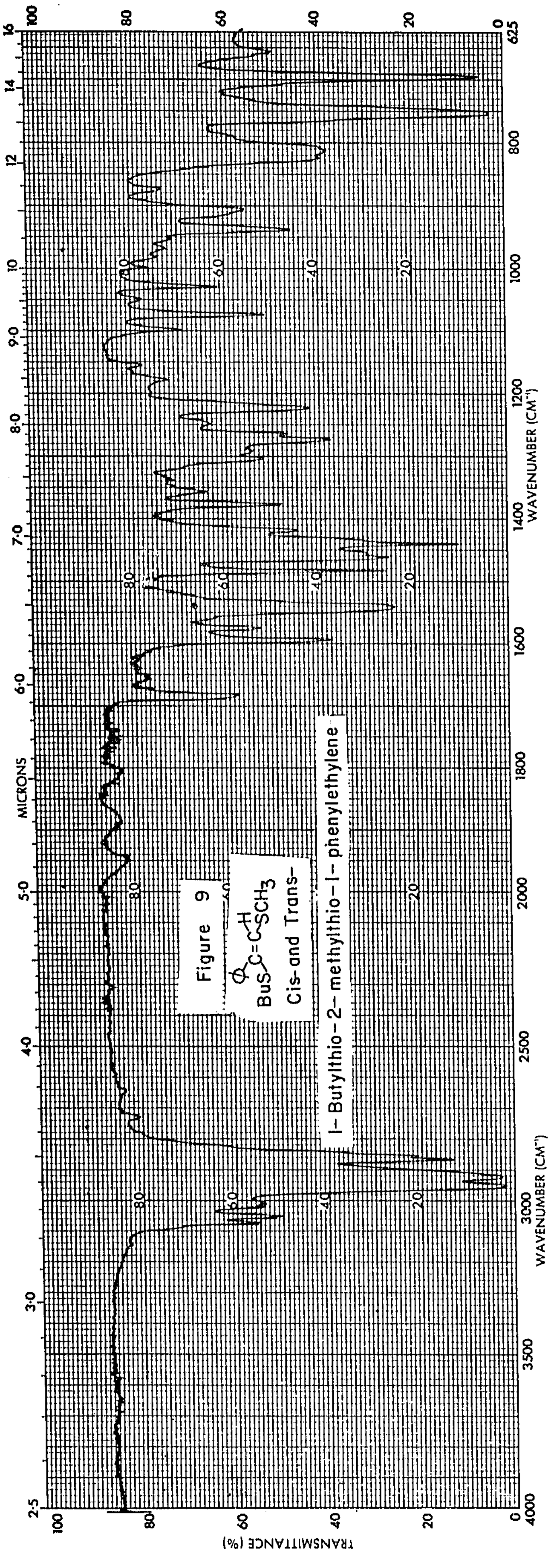


Figure 9

Φ, H: BuS–C=C–SCH_3

Cis- and Trans-

1-Butylthio-2-methylthio-1-phenylethylene

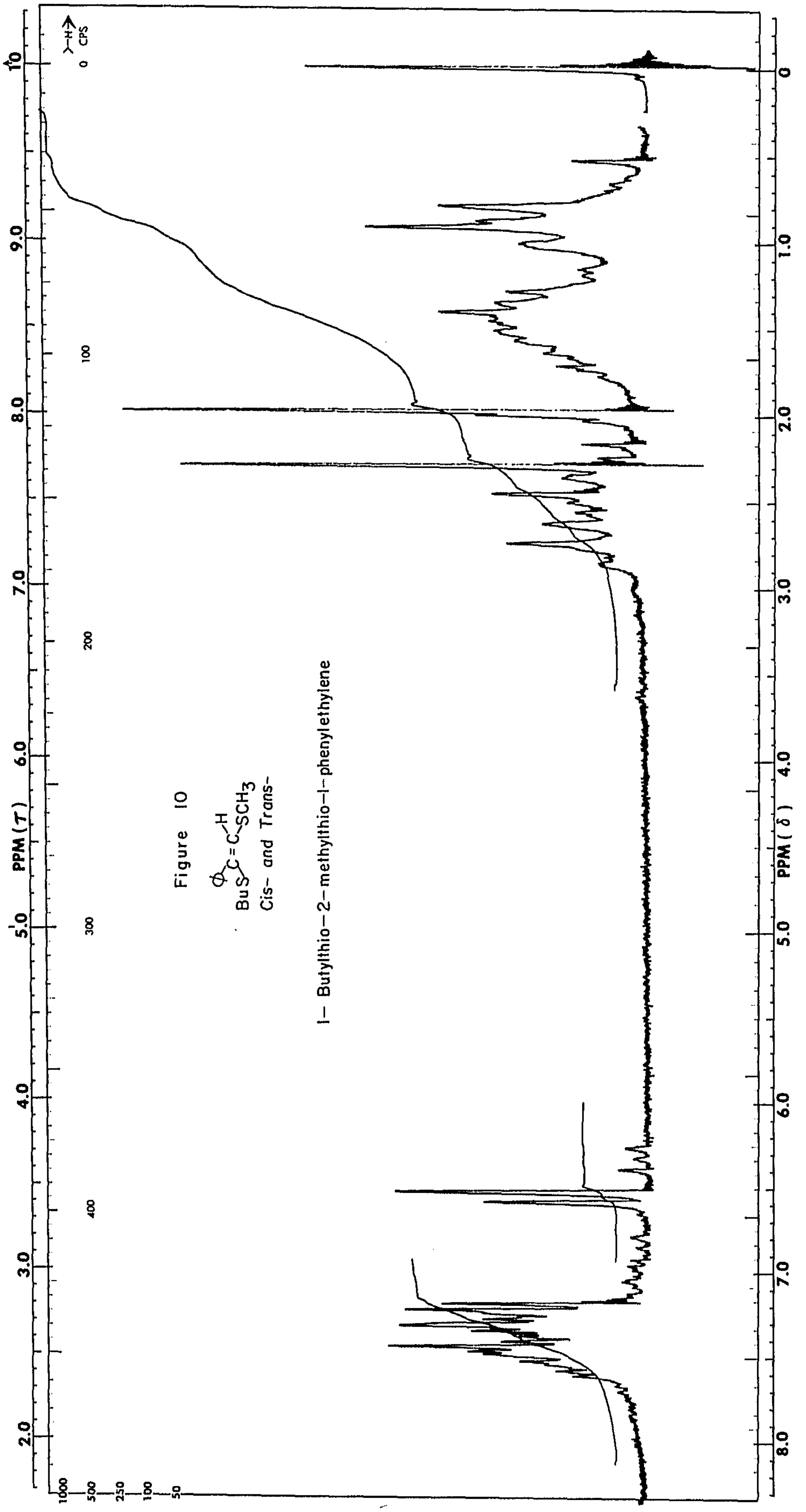
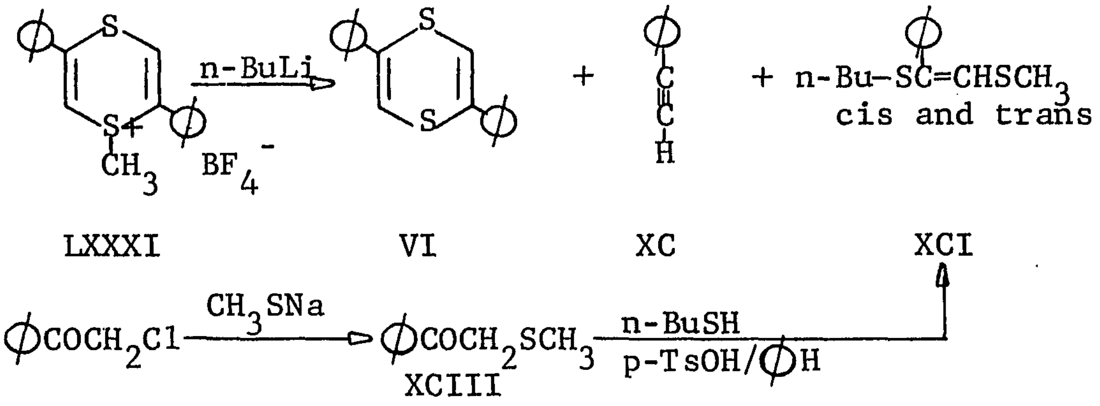


Figure 10

Cis- and Trans-

1– Butylthio-2-methylthio-1-phenylethylene

(XCIII) and 1-butanethiol in the presence of p-toluenesulfonic acid with azeotropic water separation.



Both the infrared and nmr spectra obtained from both sources were comparable. (*cf*. Figures 9 and 10). In the nmr spectra singlets appeared at δ6.58 and δ6.53 assigned to the vinyl proton and at δ2.30 and δ1.97 assigned to the S-methyl protons of the cis and trans isomers. Since 88% of the material was accounted for after the reaction (based on the amount of salt LXXXI used) and since none of the other cleavage product (XCII) was found, it is doubtful whether XCII was produced at all during the ring cleavage. Since attack by the butyl carbanion at S-4 is required for the formation of XCI, S-4 then has some partial positive character as suggested in resonance forms VIIa and VIIb as well as by the nmr spectrum of bromodithiinium salt LXXXV.

In an attempt to generate a sulfonium ylid (XCIV), uncomplicated by the nucleophilic displacement encountered

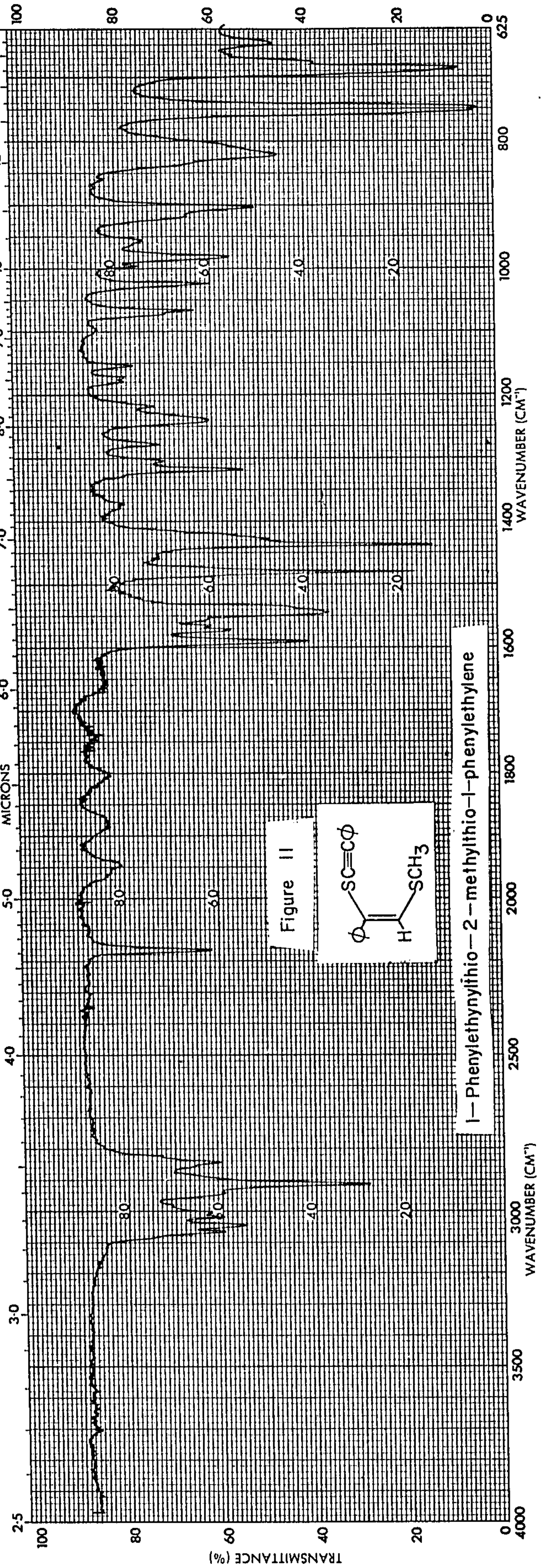


Figure 11

1—Phenylethynylthio—2—methylthio—1—phenylethylene

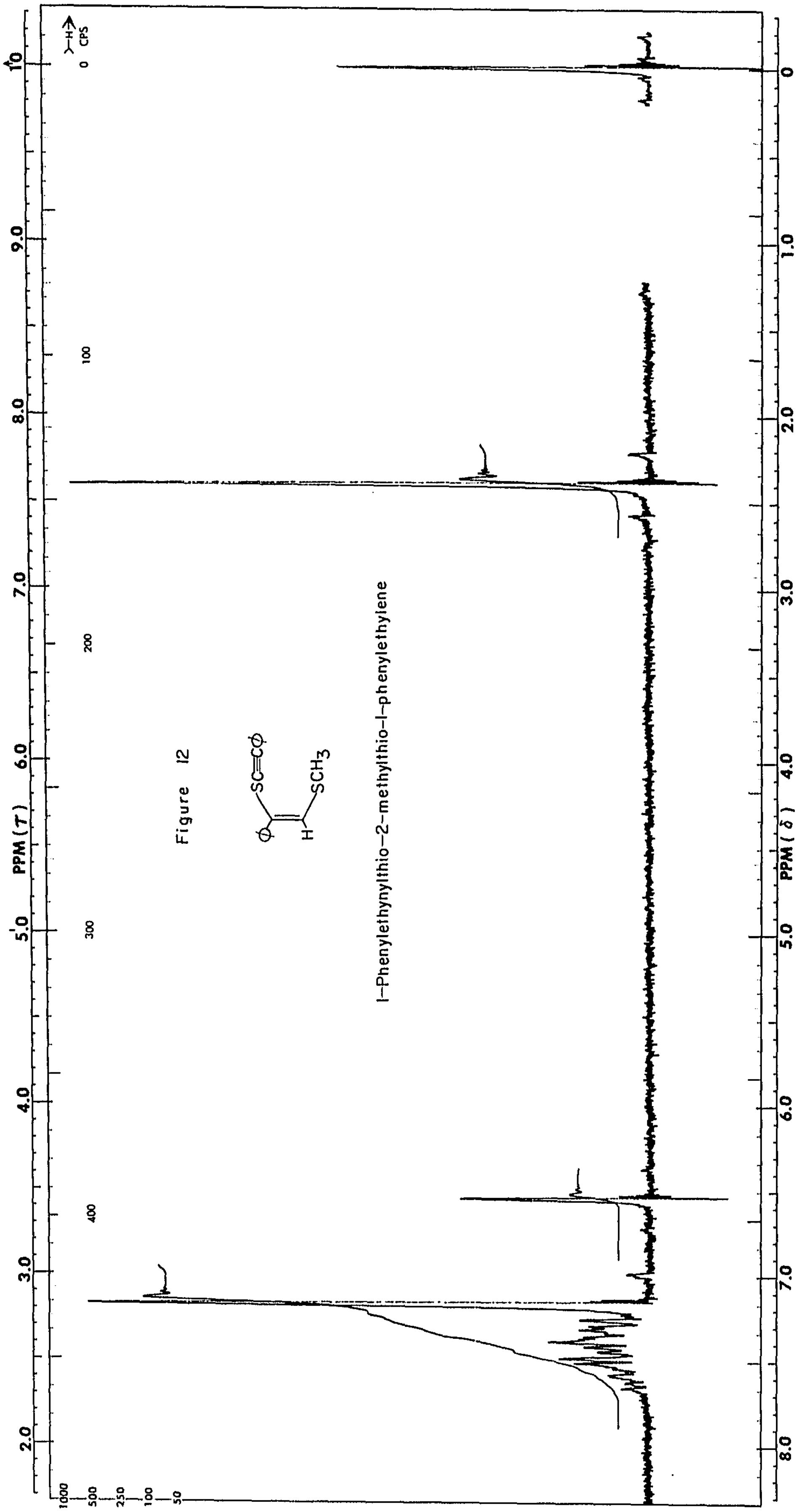
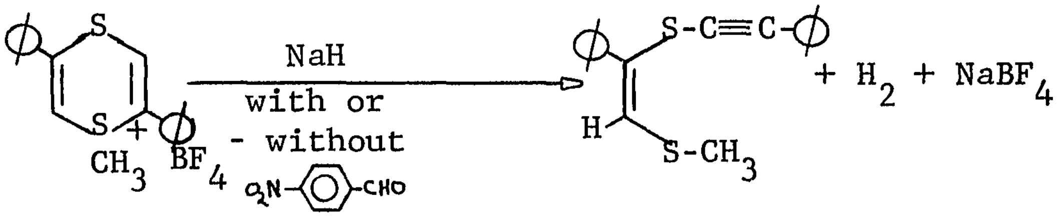


Figure 12

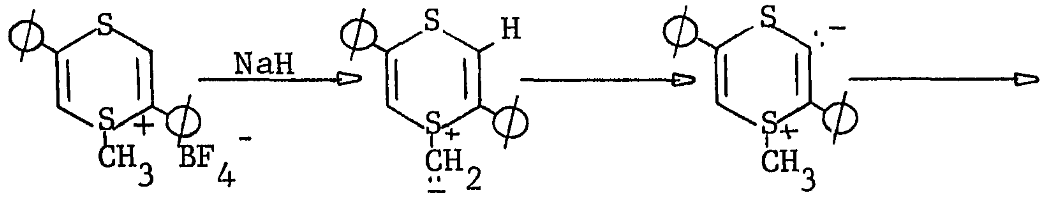
1-Phenylethynylthio-2-methylthio-1-phenylethylene in the reaction with n-butyllithium, salt LXXXI was treated with sodium hydride in glyme in the presence of p-nitrobenzaldehyde which was to act as an ylid trap.[56] At -10° a noticeable reaction proceeded to give, after chromatographic separation of the products on silica gel, a 78% yield of colorless crystals identified as 1-phenylethynylthio-2-methylthio-1-phenylethylene (XCV) and a 96% recovery of p-nitrobenzaldehyde. The reaction was repeated without the p-nitrobenzaldehyde to give XCV in 99% yield and sodium tetrafluoroborate in quantitative yield.



LXXXI XCV

Compound XCV was characterized by its mass spectrum (parent peak: m/e , 282), infrared absorption of the ethynyl group (2160 cm^{-1}), and a well defined nmr spectrum (*cf.* Figures 11 and 12) which showed an aromatic multiplet centered at δ7.30, vinyl-H as a singlet at δ6.55, and a methyl singlet at δ2.40 in the correct integrated ratio of 10:1:3, respectively. The singlet vinyl absorption in the nmr spectrum indicated that XCV was a pure isomer and its mode of formation provides strong evidence for a cis configuration.

The fact that no p-nitrophenyloxirane was formed during the reaction of salt LXXXI with sodium hydride suggested that no ylid was formed during the course of the reaction and that hydride ion abstracted the proton at the three position to give compound XCV in a smooth, perhaps concerted reaction. However, the possibility exists that ylid XCIV could form followed by a rapid proton shift from H-3 to the ylid site to give XCV before the p-nitrobenzaldehyde could intercept the transient ylid.



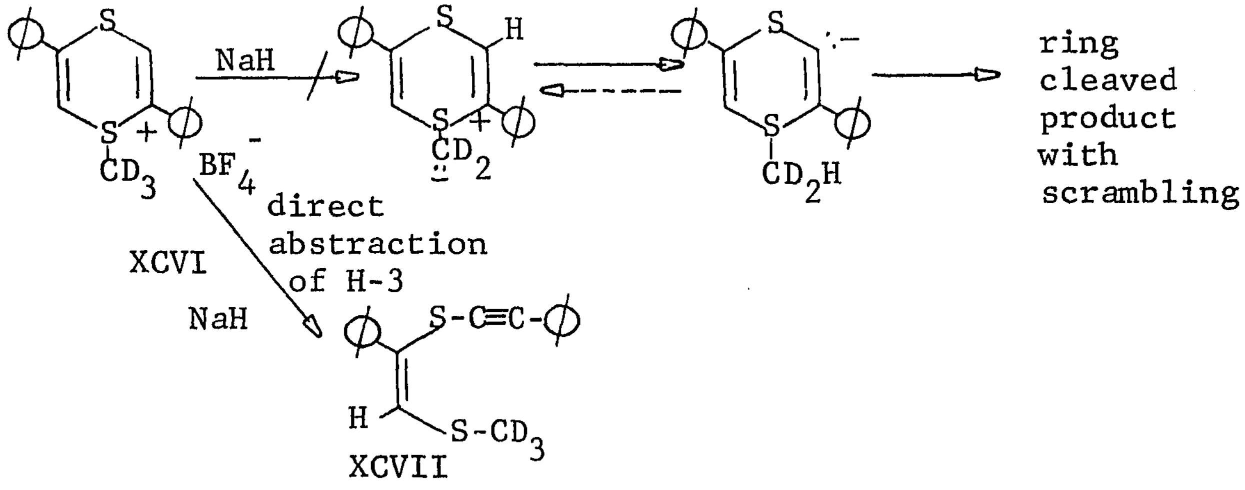
XCV

LXXXI XCIV

In order to test the hypothesis, 1-trideuteriomethyl-2,5-diphenyl-1,4-dithiinium tetrafluoroborate XCVI was prepared in the same manner as the corresponding protio compound LXXXI. If an ylid (XCIV) was formed when salt XCVI was treated with sodium hydride, scrambling of the deuterium would occur; if an ylid is not formed, there will retention of isotopic purity.

Treatment of salt XCVI with sodium hydride resulted in a 92% yield of the trideuterio analog (XCVII) of XCV with full retention of isotopic purity as demonstrated by the infrared spectrum (No C-H stretching frequencies below

3000 cm^{-1} but C-D absorption at 2130 cm^{-1} as well as the acetylenic band at 2160 cm^{-1}), the nmr spectrum (identical with spectrum of XCV but completely lacking aliphatic resonance), and the mass spectrum (parent peak: m/e , 285) of compound XCVII. It may be concluded that no ylid was formed during the course of the reaction of salt LXXXI and XCVI with sodium hydride but rather that the 3-proton was directly abstracted by hydride ion.



XCVI

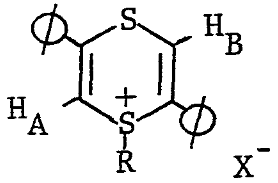
XCVII

Discussion of Spectra

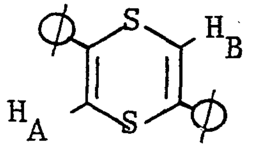
The nmr spectra of the dithiinium salts are all similar except that the 2,4,6-trinitrobenzenesulfonate salts LXXIX and LXXXII also exhibited a sharp singlet at δ 8.87 characteristic of the TNBS anion. There were only slight differences in the chemical shifts in the cation spectra resulting from counter-ion variation. As was mentioned earlier (cf. Results and Discussion section) the spectra

Table I

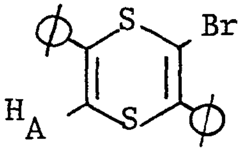
NMR Data



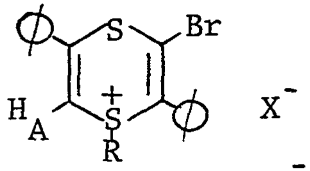
Solvent	δ, ppm H_A	H_B	X^-	R
DMSO-d_6	6.90	8.75	$TNBS^-$	CH_3
DMSO-d_6	6.90	8.75	ClO_4^-	CH_3
DMSO-d_6	6.97	8.80	$TNBS^-$	C_2H_5
CD_3CN	6.60	8.33	ClO_4^-	C_2H_5
CF_3CO_2H	6.53	8.17	ClO_4^-	C_2H_5
CD_3CN	6.58	8.28	ClO_4^-	CH_3
CF_3CO_2H	6.57	8.17	ClO_4^-	CH_3
CF_3CO_2H	6.55	8.15	BF_4^-	CH_3
CD_3CN	6.65	8.35	BF_4^-	CH_3



Solvent	H_A and H_B (δ, ppm)
DMSO-d_6	6.98
CD_3CN	6.75
$CDCl_3$	6.58



Solvent	H_A (δ, ppm)
DMSO-d_6	7.33
CD_3CN	6.98



Solvent	H_A (δ,ppm)	X^-	R
DMSO-d_6	7.08	ClO_4^-	CH_3
CD_3CN	6.73	ClO_4^-	CH_3

of the dithiinium salts have an olefinic proton shifted downfield while the other olefinic proton is shifted only slightly upfield compared with dithiin VI. Since Caserio[10] has demonstrated unambiguously that the sulfonium center of vinyl sulfonium salts selectively and strongly deshields the protons β to the sulfonium center and in the light of the results already described (namely the attack of the butyl carbanion at S-4 and the exclusive removal of the proton in the 3-position by hydride ion) it may be concluded that the tentative assignment of the upfield proton in bromodithiinium salt LXXXV to H-6 was in fact correct, while for the 1-alkyl-2,5-diphenyl-1,4-dithiinium salts the downfield proton may be assigned to H-3.

The ultraviolet-visible spectrum of dithiin VI consists of 3 bands which can be assigned to $\pi \rightarrow \pi^*$ transitions of the two phenyl groups (261 mμ), the double bonds conjugated with the sulfur atoms (308 mμ), and a transition of the non-bonding electrons on the sulfur atoms (340 mμ). This transition may be $n \longrightarrow \pi^*$ or $n \longrightarrow d$[17] but at this time no definite assignment can be made (cf. Figure 13). The long wavelength transition for bromodithiin LXXXIV is probably submerged under the $\pi \rightarrow \pi^*$ transition associated with the conjugated bis-vinylsulfide system (cf. Figure 14).

FIGURE 13
Ultraviolet-Visible Spectrum of
2,5-Diphenyl-1,4-dithiin

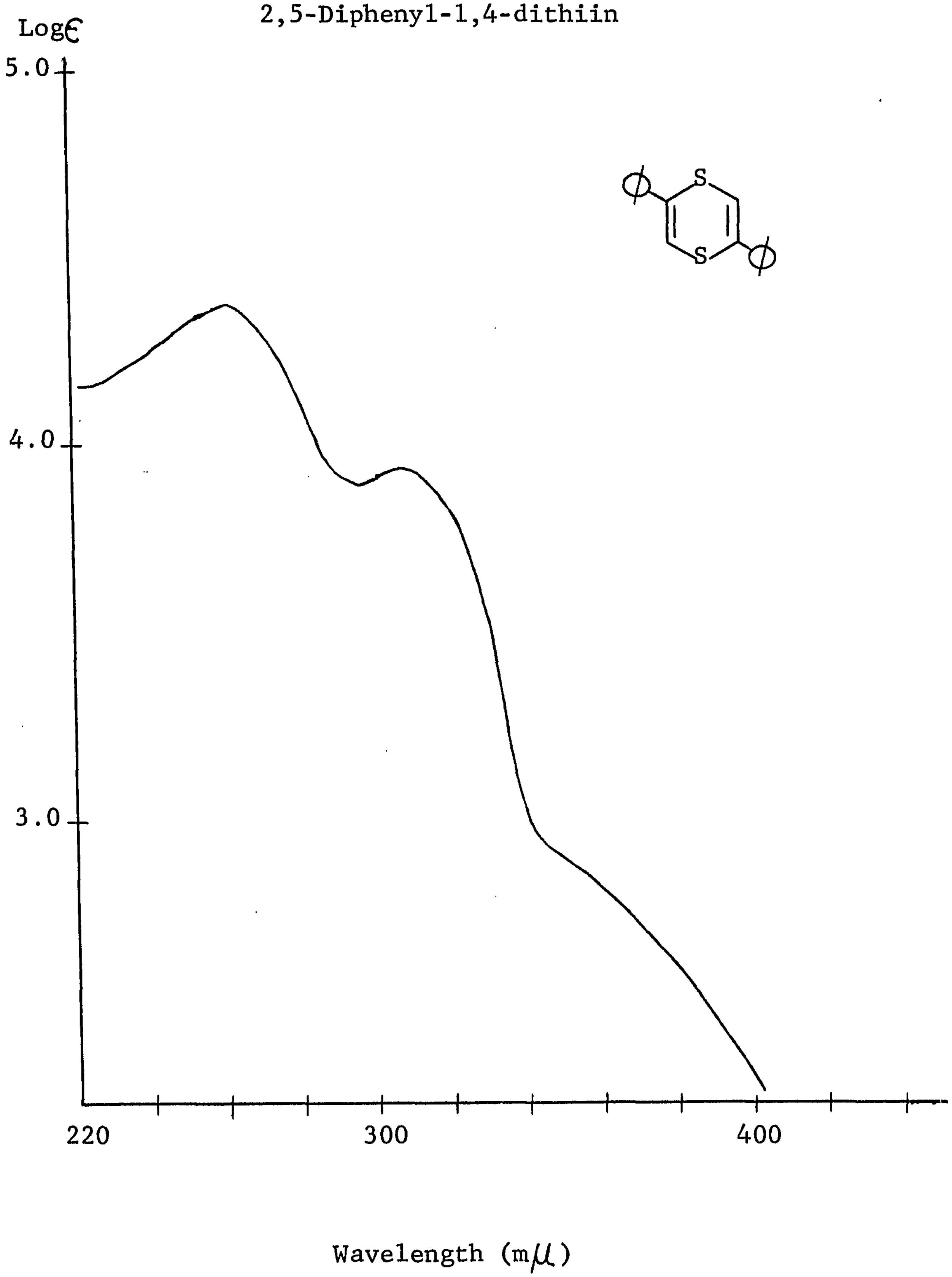
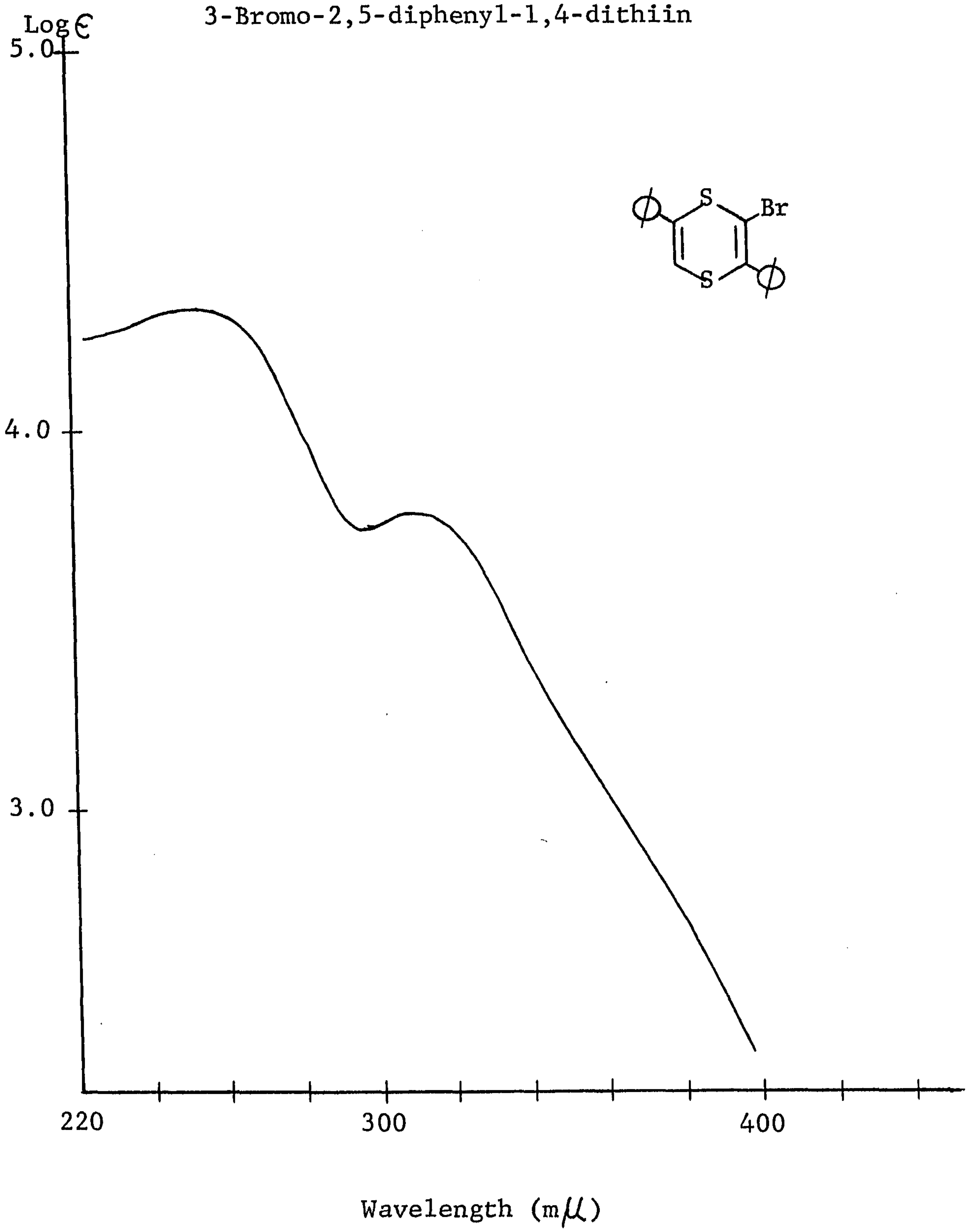


FIGURE 14

Ultraviolet-Visible Spectrum of
3-Bromo-2,5-diphenyl-1,4-dithiin



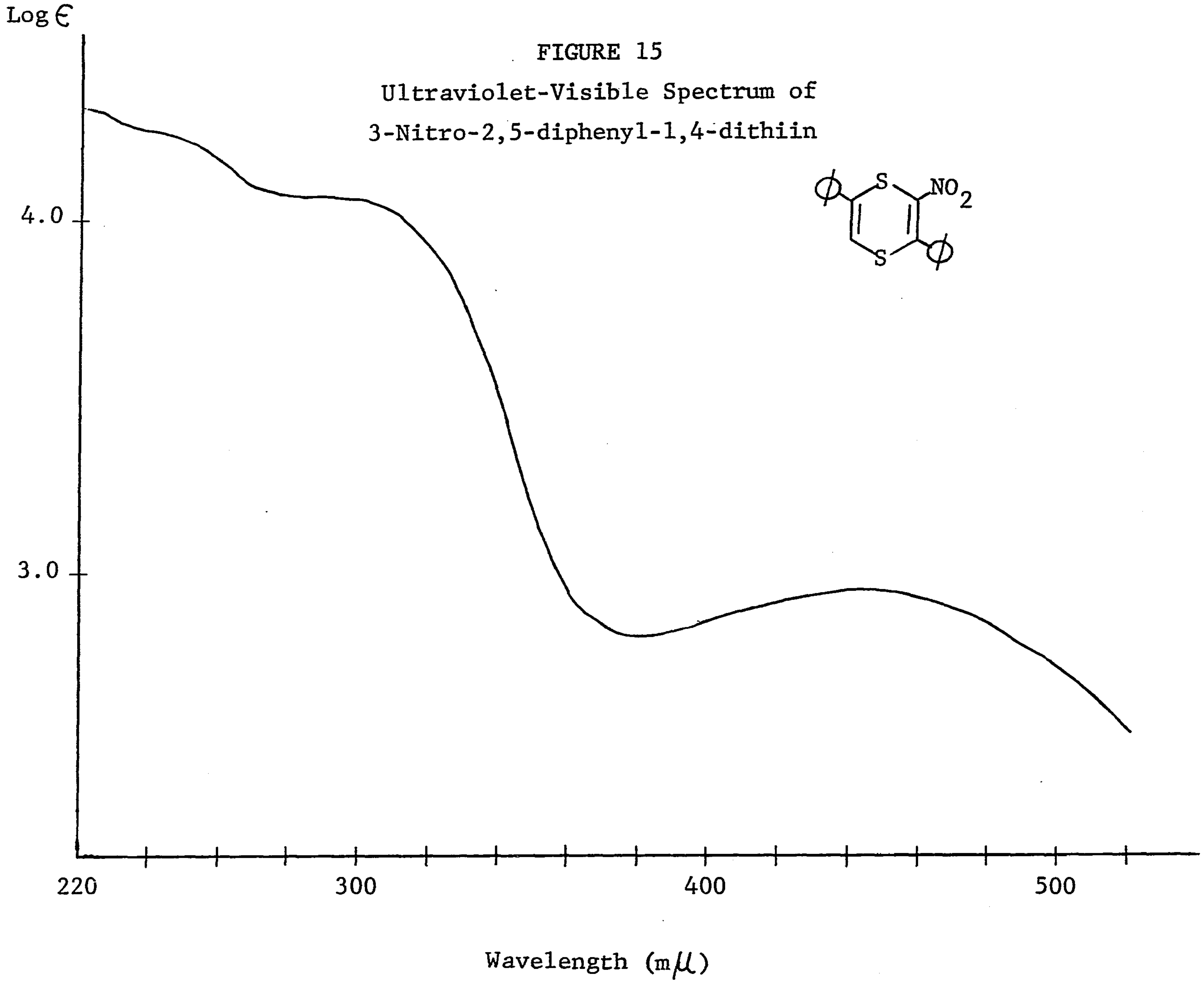


FIGURE 15

Ultraviolet-Visible Spectrum of
3-Nitro-2,5-diphenyl-1,4-dithiin

FIGURE 16

Ultraviolet-Visible Spectrum of 1-Methyl-2,5-diphenyl-1,4-dithiinium Tetrafluoroborate

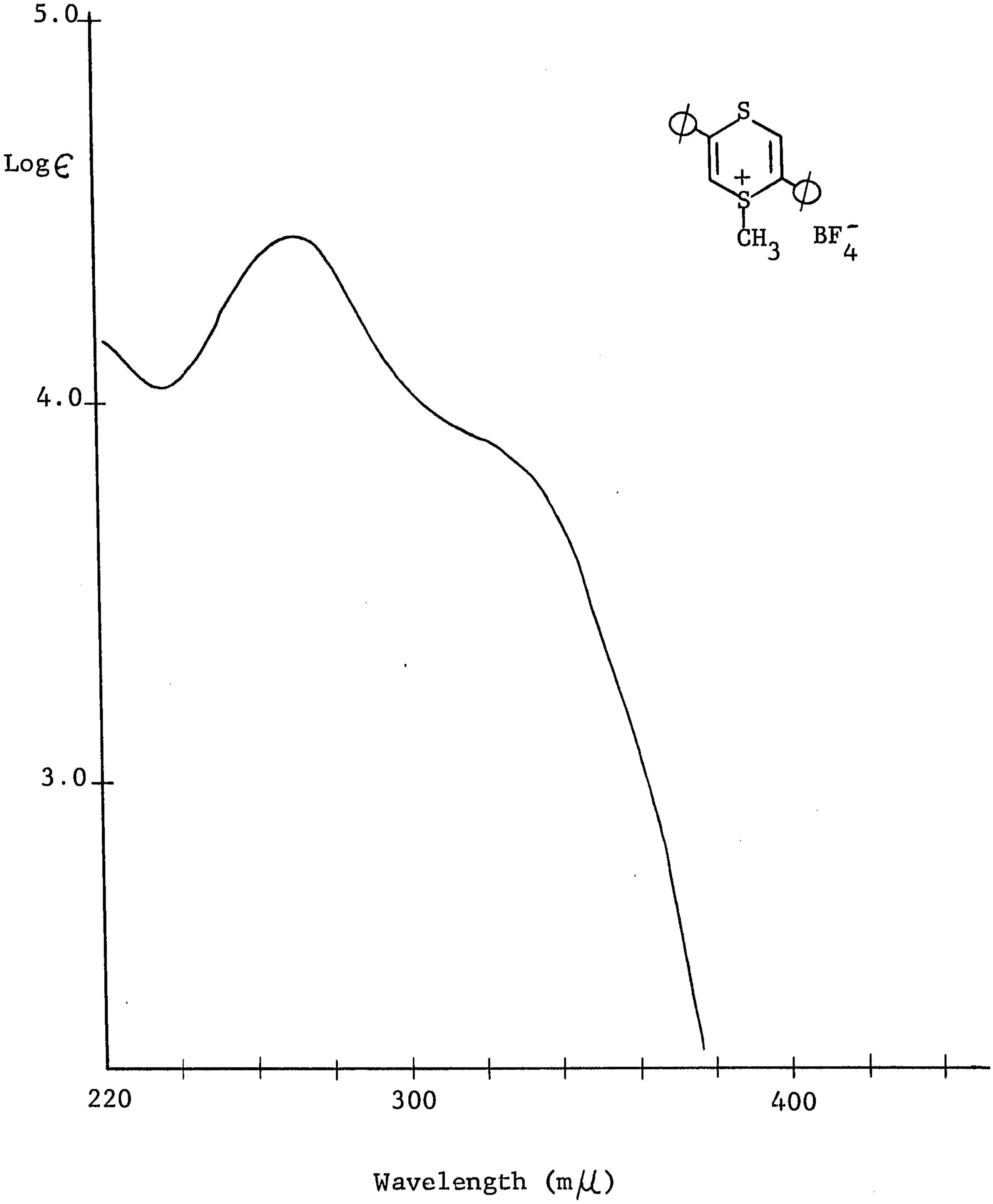
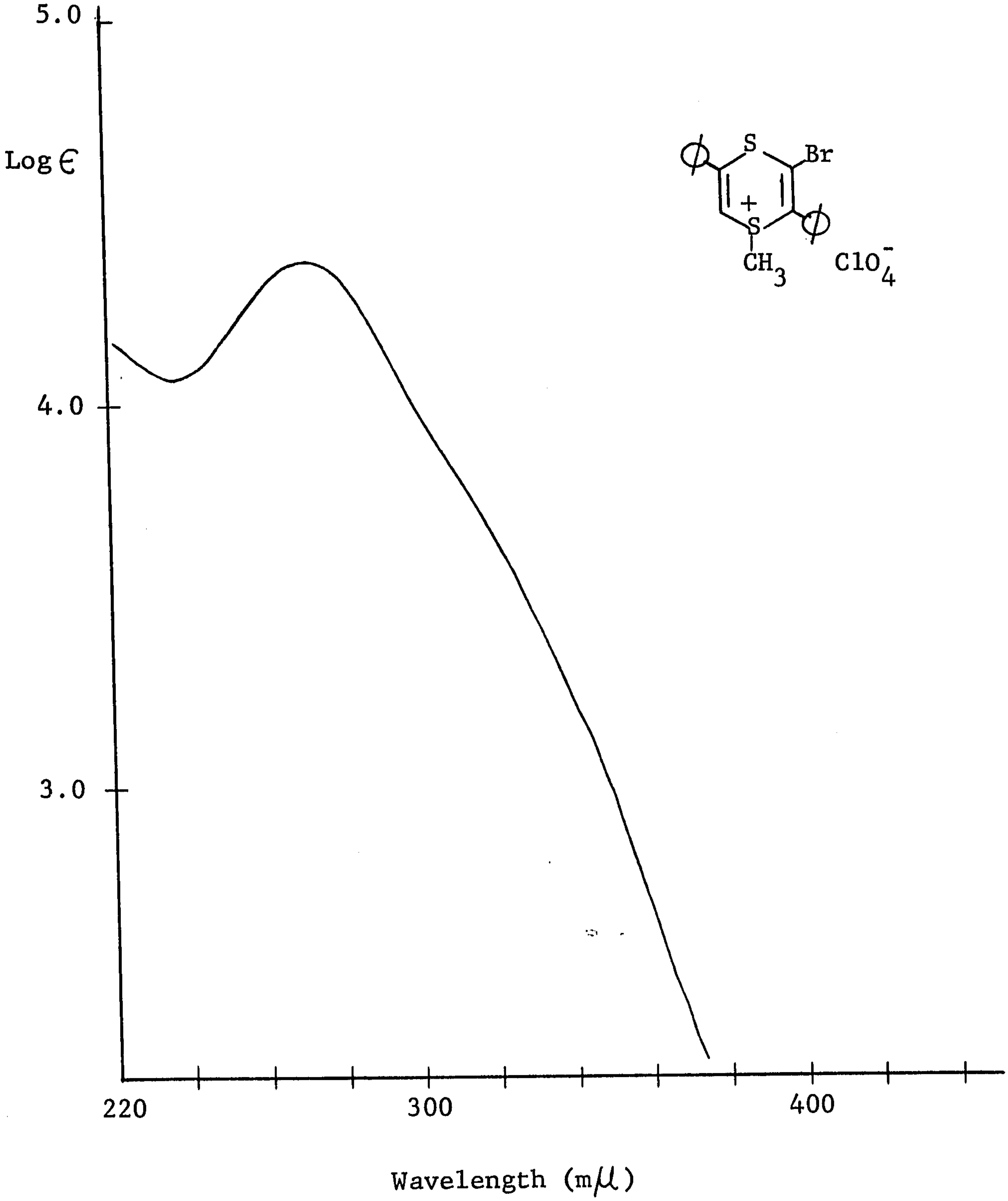


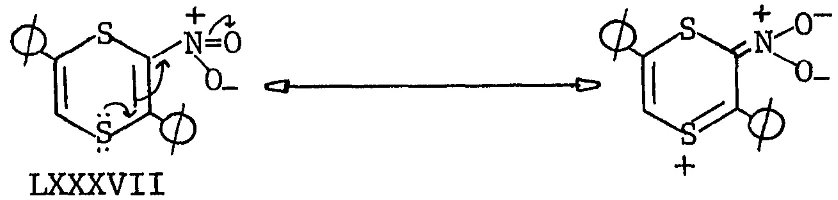
FIGURE 17

Ultraviolet-Visible Spectrum of

1-Methyl-3-bromo-2,5-diphenyl-1,4-dithiinium Perchlorate



The red color of nitrodithiin LXXXVII can be attributed to contributions from resonance forms such as LXXXVIIa in which a sulfur atom is conjugated with the nitro group.



LXXXVII

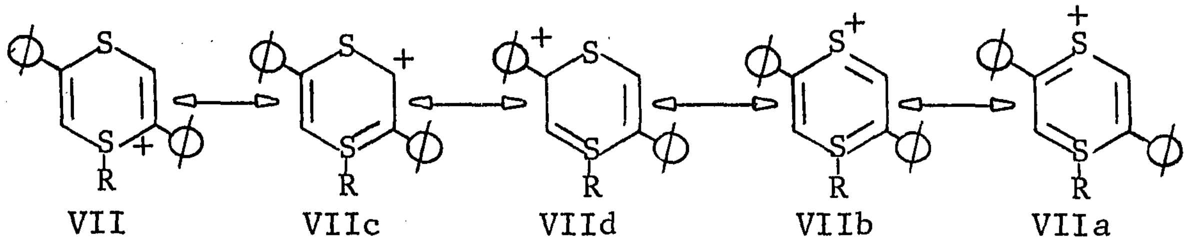
LXXXVIIa

A π-π^* transition at 442 mμ confirms the existence such forms as LXXXVIIa (cf. Figure 15).

Alkylation of dithiins VI and LXXXIV generated colorless salts whose ultraviolet-visible spectra have two bands. (cf. Figures 16 and 17). Except for the disappearance of the $n \rightarrow \pi^*$ or $n \rightarrow d$ band in the salt of dithiin VI, the ultraviolet-visible spectra were quite similar to the parent dithiins VI and LXXXIV. It may be concluded then that the π-electron systems of the salts are quite similar to the π-electron systems of the parent dithiins and that the π-electron systems of the salts differ markedly from Price's intensely colored S-phenylthiaaromatics, e.g. 1-phenyl-1-thianaphthalene (I), the only known compounds presumably invoking cyclic conjugation via $2p\pi$-$3p\pi$ overlap of carbon and sulfur with the p-electrons promoted to the d-level.[7]

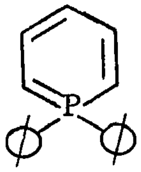
In conclusion the following statements can be made concerning 1-alkyl-2,5-diphenyl-1,4-dithiinium salts:

1. There is d-orbital participation at the sulfonium center as is shown by the nmr spectra as well as by the experimental evidence presented. This result is in agreement with Caserio's results for which she postulated that the strong deshielding of the β-protons in vinylsulfonium salts is a consequence of d-orbital participation by the sulfonium center which places a substantial positive charge on the β-carbon atom. For the dithiin system, stabilization of the β-carbonium ions is possible if S-4 donates a pair of electrons to the system to generate a new thionium center.[18] At least some contribution is made by S-4 since the butyl carbanion attacked there.



2. There is no ring current (nmr and ultraviolet-visible spectra) in the salts because there is no cyclic conjugation.

3. The lack of cyclic conjugation may be a result of the fact that the ring is still puckered in the salt preventing effective overlap around C_3-S-C_5. Another possibility suggested by Markl[19] is that the d-orbitals of S-1 are themselves orthogonal and non-conducting. Such a situation would prevent cyclic conjugation and hence, no ring current would be observed. There is lack of evidence of through-conjugation for Markl's 1,1-diphenyl-1-phosphabenzene (XCVIII).[19]



Experimental Section

Melting points were determined in capillary tubes using a Mel-Temp appartus (Laboratory Devices, Cambridge, Mass.) and are corrected. Ultraviolet-visible spectra were recorded on a Beckman DK-2A spectrophotometer and the infrared spectra were obtained on a Perkin-Elmer 257 instrument. Nmr spectra were determined on a Varian A-60 spectrometer using tetramethylsilane as internal standard, and data are presented in the order δ (multiplicity, number of protons, assignment). Mass spectra were run by Dr. J. E. Sturm on a Hitachi 6E high resolution instrument equipped with double focusing sector. Microanalyses were performed by Dr. V. B. Fish and by Galbraith Microanalytical Laboratories, Knoxville, Tenn.

3-Phenylthio-3-phenylpropionic Acid (XIV).-This compound was prepared following the method of F. Arndt.[20]

To a slurry of 300.0 g (2.02 mols) of cinnamic acid in 900 ml of glacial acetic acid warmed to about 50° was added 200 ml of aqueous 48% hydrobromic acid. To this mixture was added 239.0 g (2.17 mols) of thiophenol. When the mixture was heated to 100°, a clear solution which was heated and stirred overnight was obtained. When the stirring was discontinued, the clear solution separated into two layers. The mixture was then steam distilled to remove excess thiophenol. Then the oily mixture was allowed to separate into two layers, and the product (lower layer) was collected. When the oily product was poured into cold petroleum ether (bp 60-70°) and scratched with a glass rod, 505.0 g (97%) of yellow crystals with mp 70-80° separated. One recrystallization from benzene/60-70° petroleum ether gave tan crystals with mp 83-86° (lit.[20] mp 85-86°).

<u>2-Phenylthiachroman-4-one</u> (XI).-This compound was prepared by a modification of the method of F. Arndt.[20,21]

The 3-phenylthio-3-phenylpropionic acid obtained in the previous preparation was recrystallized from cyclohexane and air dried to give white crystals with mp 82-84°. The toluene used in the preparation was dried over "Dri Na" and the "Celite" was dried overnight at 200°.

A solution of 75.0 g (0.290 mol) of 3-phenylthio-3-phenylpropionic acid dissolved in 375 ml of toluene was heated to reflux and stirred rapidly. A slurry consisting of 45 g of "Celite" and 83 g of phosphorous pentoxide in 375 ml of toluene was added to the solution of the acid. After the resulting mixture was refluxed and stirred for ½ hr, a slurry consisting of 83 g of phosphorous pentoxide in 300 ml of toluene was added to the reaction mixture.

After an additional 90 min reflux period, the reaction mixture was cooled slightly and then filtered through a sintered glass funnel. The red-brown residue was extracted three times with 150 ml of hot toluene. The extracts were combined with the filtrate and the toluene was evaporated to give a viscous oil which was distilled to give 47.5 g (68%) of light yellow product with bp 159-162^o (0.1 mm). The yellow liquid did not solidify so that a melting point could not be taken. A 2,4-dinitrophenylhydrazone was prepared from the yellow oil to give an orange product with mp 236-237^o.

Anal. Calcd for $C_{21}H_{16}N_4O_4S$: C, 59.99; H, 3.84; N, 13.33; S, 7.62. Found: C, 59.97; H, 4.06; N, 13.38; S, 7.65.

2-Phenylthiachroman-4-ol (XV).-This compound was prepared essentially following the method of Luttringhaus *et. al.*[23]

The tetrahydrofuran used in this preparation was dried over lithium aluminum hydride and distilled directly into the reaction vessels.

To a slurry of 2.30 g (0.0607 mol) of lithium aluminum hydride in 120 ml of tetrahydrofuran was added over a period of 45 min a solution of 56.3 g (0.235 mol) of 2-phenylthiachroman-4-one dissolved in 75 ml of tetrahydrofuran.

After the reaction mixture was stirred for an additional 30 min, absolute ethanol was added dropwise to the resulting slurry until the evolution of gas was no longer observed. The reaction mixture was filtered to remove the lithium salts and the filtrate was evaporated to yield a yellow solid which was dissolved in hot benzene. Petroleum ether (60-70°) was added to the hot benzene solution until the cloud point was reached. On cooling, 40.4 g (71%) of white solid with mp 145-147° (lit.[23] mp 144-145°) precipitated from the solution.

Reaction of 2-Phenylthiachroman-4-ol (XV) with Fused Potassium Pyrosulfate in vacuo.-This reaction was conducted essentially according to the method of Parham and Koncos.[24]

An intimate mixture consisting of 10.0 g (0.0414 mol) of 2-phenylthiachroman-4-ol and 1.0 g of finely pulverized, fused potassium pyrosulfate was placed in a pear shaped flask fitted with a connecting adapter and thermometer, a short condenser cooled with steam, and a fraction cutter. The system was evacuated to 0.35 mm and then the flask was heated in a sand bath until the sand temperature reached 190-200°. A yellow oil distilled at 138-145° (0.35 mm). This material was redistilled to give 5.50 g of a pale yellow oil with bp 138-141° (0.30 mm). The nmr spectrum of the yellow oil indicated that it was a 50-50% mixture of 2-phenyl-2H-(1)-benzothiapyran and 2-phenyl-4H-(1)-benzothiapyran. 2-Phenyl-2H-(1)-benzothiapyran in the mixture; nmr (CCl_4) δ ca 7.17 (m,9, aryl), 6.47 (d with allylic coupling, 0.5, J=10 Hz, H-4), 5.79 (q, 0.5, J=5.0 Hz, H-3), 4.72 (d with allylic coupling, 0.5, J=5 0 Hz, H-2). 2-Phenyl-4H-(1)-benzothiapyran in the mixture; nmr (CCl_4) δca 7.17 (m,9, aryl), 6.08 (t, 0.5, J=5.0 Hz, H-3), 3.35 (d, 1.0, J=5.0 Hz, H-4). The experiment was then repeated as described above except that after the reaction mixture was brought to 190-200°, the heat was removed for 30 min and then the material was distilled to give 13.6 g (81%) of a yellow oil with bp 165-170° (1.50 mm). Two more distillations gave a nearly colorless oil with bp 119-121° (0.05 mm). The nmr spectrum of the nearly colorless oil indicated that it was a 67-33% mixture of 2-phenyl-4H-(1)-benzothiapyran and 2-phenyl-2H-(1)-benzothiapyran, respectively. 2-Phenyl-2H-(1)-benzothiapyran in the mixture; nmr (CCl_4) δ ca 7.17 (m,9, aryl), 6.47 (d with allylic coupling, 0.33, J=10 Hz, H-4), 5.79 (q, 0.33, J=5.0 Hz, H-3), 4.72 (d with allylic coupling, 0.33, J=5.0 Hz, H-2). 2-Phenyl-4H-(1)-benzothiapyran in the mixture; nmr (CCl_4) δca 7.17 (m,9, aryl), 6.08 (t, 0.67, J=5.0 Hz, H-3), 3.35

(d, 1.33, J=5.0 Hz, H-4).

2-Phenyl-3-bromothiachroman-4-one (XVIII).- This compound was prepared by an improved modification of the procedure described by Arndt *et*. *al*.[25]

To a solution of 47.5 g (0.198 mol) of 2-phenylthiachroman-4-one dissolved in 100 ml of glacial acetic acid was added over a period of 3 hr 31.5 g (0.198 mol) of bromine. The reaction mixture was well stirred and the temperature of the reaction was maintained at about 14° so that the reaction mixture had the consistency of slush. The yellow-white reaction mixture was stirred an additional 30 min and then was poured into benzene. The layers were separated and the benzene layer was washed three times with a 5% aqueous sodium hydrogen sulfite solution, two times with a 5% aqueous sodium carbonate solution, two times with water, and finally dried over anhydrous magnesium sulfate. The benzene was evaporated and the red residue was recrystallized from 95% ethanol to give 35.6 g (56.6%) of white crystals with mp 132-134° (lit.[25] mp 135°).

2-Phenylthiachromone (XIX).-This compound was prepared using a modification of the procedure described by Warnhoff *et*. *al*.[26]

Nitrogen was bubbled through a stirred solution consisting of 19.4 g (0.0608 mol) of 2-phenyl-3-bromothiachroman-4-one and 2.57 g (0.0608 mol) of lithium chloride dissolved in 45 ml of dimethylformamide. The solution was then heated to 100° for 35 min. After this heating period, nearly all of the solvent was removed, and the yellow residue was extracted into about 500 ml of boiling toluene. The toluene was evaporated and the yellow solid was recrystallized from 95% ethanol to give 12.9 g (89%) of a yellow solid with mp 123-125° (lit.[25] mp 126-127°).

Attempted Preparation of the N,N-Dimethylhydrazone (XXI) of 2-Phenylthiachromone (XIX).-This reaction was attempted essentially following the procedure of Newkome and Fishel.[29]

To a stirred and heated solution of 4.0 g (0.017 mol) of 2-phenylthiochromone in 40 ml of absolute ethanol was added a solution of 4.0 g (0.067 mol) of unsym-N,N-dimethylhydrazine 10 ml of absolute ethanol. The resulting solution was refluxed overnight. On cooling, a solid separated from the solution. Recrystallization of the solid gave white crystals with mp 121-122°. A mixed melting point with 2-phenylthiochromone was essentially undepressed.

2-Phenyl-4H-(1)-benzothiapyran (XVI).-Nitrogen was bubbled through a stirred mixture of 20.0 g (0.084 mol) of 2-phenylthiachromone in 75 ml of methanol. The mixture was heated to reflux, and then a solution of 19.1 g (0.504 mol) of sodium borohydride, 100 ml of water, and 1.0 ml of 50% aqueous sodium hydroxide was added. The resulting mixture was refluxed for 5 hr and then cooled to give a yellow oil. The oil layer was separated and the aqueous layer was extracted with benzene. The oil layer and the benzene extract were combined and dried over anhydrous magnesium sulfate. The benzene was evaporated to give a pale yellow solid. The yellow solid was then sublimed at 45-50° (0.20 mm) to give 12.8 g (81%) of nearly white crystals with mp 58-62°. A sample was distilled at 137-138° (0.25 mm) and then sublimed at 54° (0.05 mm) to give white crystals with mp 59-62° (lit.[23] mp 63-64°).

Anal. Calcd for $C_{15}H_{12}S$: C, 80.31; H, 5.39; S, 14.29 Found: C, 80.18; H, 5.32; S, 14.08.

Reaction of a Mixture of 2-Phenyl-2H-(1)-benzothiapyran (XVII) and 2-Phenyl-4H-(1)-benzothiapyran (XVI) with Diethyl bromoacetal and Silver 2,4,6-Trinitrobenzenesulfonate.- To a stirred solution of 1.00 g (1.91 mmol) of silver 2,4,6-trinitrobenzenesulfonate dissolved in 5 ml of nitromethane and 5 ml of methylene chloride was added from separate dropping funnels a solution of 0.40 g (2.03 mmols) of diethyl bromoacetal in 6 ml of methylene chloride and another solution of 0.43 g (1.91 mmol) of compounds XVI and XVII in 6 ml of methylene chloride. After stirring for 15 min, the resulting yellow solution was heated to reflux for 30 min. A silver mirror and a finely divided black precipitate formed gradually during the 30 min reflux. No further separation was attempted.

Reaction of a Mixture of 2-Phenyl-2H-(1)-benzothiapyran (XVII) and 2-Phenyl-4H-(1)-benzothiapyran (XVI) with Phenacyl Bromide and Silver 2,4,6-Trinitrobenzenesulfonate.- To a stirred solution of 1.00 g (1.91 mmol) of silver 2,4,6-trinitrobenzenesulfonate dissolved in 5 ml of nitromethane and 5 ml of methylene chloride was added from separate dropping funnels a solution of 0.40 g (2.02 mmols) of phenacyl bromide in 6 ml of methylene chloride and another solution of 0.43 g (1.91 mmol) of compounds XVI and XVII in 6 ml of methylene chloride. The resulting solution gradually became yellow and a finely divided precipitate began to form. The slurry was heated to reflux for 20 min during which time a silver mirror and a black precipitate formed. The mixture was filtered hot and the filtrate was evaporated to dryness. Tlc of the filtrate indicated the presence of unreacted phenacyl bromide, acetophenone, and several unidentified compounds. Methylene chloride and ether were added to the dark residue. After standing for 48 hr, a small amount of yellow solid separated. The yellow solid slowly decomposed above 200°.

Reaction of a Mixture of 2-Phenyl-2H-(1)-benzothiapyran XVII and 2-Phenyl-4H-(1)-benzothiapyran (XVI) with Benzyl Bromide and Silver 2,4,6-Trinitrobenzenesulfonate.-To a stirred solution (cooled to -15°) of 1.00 g (1.91 mmol) of silver 2,4,6-trinitrobenzenesulfonate dissolved in 5 ml of nitromethane and 5 ml of methylene chloride was added a solution of 0.33 g (1.93 mmol) of benzyl bromide in 6 ml of methylene chloride. Then a solution of 0.43 g (1.91 mmol) of compounds XVI and XVII in 6 ml of methylene chloride was added dropwise. After 3 min of addition, a yellow-white precipitate began to separate. The mixture was stirred for 45 min at -15°. The solvents were then evaporated and the residue was added to about 50 ml of glacial acetic acid. After heating the mixture for 10 min on a steam bath the undissolved solid was removed by filtration. On cooling the filtrate yielded yellow crystals which gradually decomposed above 200° to a green semi-solid which melted at 235-237°. Two more recrystallizations from glacial acetic acid gave 2-phenyl-1-thianaphthalenium 2,4,6-trinitrobenzenesulfonate (identical with material material prepared in the next experiment) which decomposed above 230° to a green semi-solid which melted 240-241°; uv max (MeCN) 265 $m\mu$ ($\log\epsilon$ 4.57), 290 (4.40) sh, 399 (4.40).

Anal. Calcd for $C_{21}H_{13}N_3O_9S_2$: C, 48 92; H, 2.54; N, 8.15; S, 12.44. Found: C, 48.98; H, 2.65; N, 8.25; S, 12.53.

2-Phenyl-1-thianaphthalenium 2,4,6-Trinitrobenzenesulfonate (XXVII).-To a well stirred slurry of 2.86 g (0.011 mol) of triphenylcarbinol in 40 ml of acetic anhydride heated to 130° and then cooled to 10° was added 3.62 g (0.011 mol) of 2,4,6-trinitrobenzenesulfonic acid dihydrate to give a yellow-brown precipitate. After the mixture came to room temperature, a solution of 2.24 g (0.010 mol) of 2-phenyl-4H-(1)-benzothiapyran in 10 ml of glacial acetic acid was added dropwise to give a yellow precipitate. The reaction mixture was stirred for an additional 10 min, filtered, and the precipitate was washed with ether and air dried to give 5.10 g (99%) of bright yellow product. Two recrystallizations from glacial acetic acid gave analytical material with mp 247-248° dec. with color change and softening above 235°; uv max (MeCN) 265 $m\mu$

(log ϵ 4.57), 290 (4.40) sh, 399 (4.40).

Anal. Calcd for $C_{21}H_{13}N_3O_9S_2$: C, 48.92; H, 2.54; N, 8.15; S, 12.44. Found: C, 49.13; H, 2.60; N, 8.12; S, 12.59.

2-Bromobenzaldehyde (XXXIV).-This compound was prepared using a procedure for the synthesis of 4-bromobenzaldehyde described by Lieberman and Connor.[37]

In a 2 liter flask equipped with an efficient stirrer and surrounded by an ice-salt bath were placed 570 ml of glacial acetic acid and 400 ml of acetic anhydride. To this solution was added slowly 85 ml of concentrated sulfuric acid. When the temperature was 0-5°, 62.0 g (0.362 mol) of 2-bromotoluene was added. A slurry of 100 g (1.00 mol) of chromium trioxide in 165 ml of acetic anhydride was prepared and was added dropwise at such a rate that the temperature of the reaction mixture remained below 10°. The reaction mixture was stirred for an additional 10 min after the addition was complete. The reaction mixture was poured into two 4 liter beakers 2/3 filled with chipped ice and then cold water was added until the total volume was 6 liters. When all of the ice melted, the green mixture was filtered to give a green-white solid which was washed until the filtrate was colorless. Then the solid was slurried in 500 ml of a cold 2% sodium carbonate solution. The white 2-bromobenzaldehydediacetate was collected by filtration; the product was washed with cold water, and finally was washed with 20 ml of cold 95% ethanol.

The 2-bromobenzaldehydediacetate was converted to 2-bromobenzaldehyde by refluxing for 30 min the white solid obtained above with 100 ml of water, 150 ml of 95% ethanol and 10 ml of concentrated sulfuric acid. The resulting solution was filtered and then was evaporated to give a mixture which was extracted with benzene. The organic layer was washed with water and then was dried over anhydrous magnesium sulfate. The solvent was evaporated and the residue was distilled at reduced pressure to give 27.1 g (40.5%) of a pale yellow oil with bp 106-109° (11 mm) (lit.[38] bp 106-109° (11 mm)).

2-Bromocinnamic Acid (XXXV).-This compound was prepared by the method of Reich and Chaskelis.[39]

Into a flask were placed 27.1 g (0.146 mol) of freshly distilled 2-bromobenzaldehyde, 22.5 g (0.220 mol) of acetic anhydride, and 8.62 g (0.088 mol) of potassium acetate (previously dried at 220°). The mixture was heated in a Wood's metal bath at 175-180° for 5 hr. Then the hot reaction mixture was poured into about 500 ml of warm water.

After some stirring, the light brown solid was collected by filtration, was dissolved in boiling 95% ethanol, was treated with Norit A (neutral), and the mixture was filtered to give a clear solution. The solution was evaporated to ½ its volume and was cooled to give off-white crystals. On further concentration to ½ volume, more off white crystals were obtained. The combined yield was 19.6 g (60%) of product with mp 213-215° (lit.[39] mp 215-216°).

Reaction of 2-Bromocinnamic Acid with Thiophenol.-

Method I: in acetic acid with aqueous hydrobromic acid.[20] To a well stirred slurry of 19.6 g (0.0864 mol) of 2-bromocinnamic acid in 50 ml of glacial acetic acid was added 10.2 g (0.0925 mol) of thiophenol and 8.5 ml of 48% hydrobromic acid. The resulting mixture was heated to 110° at which temperature solution resulted. After the solution was stirred and heated overnight, the reaction mixture was indirectly steam distilled until the thiophenol was removed. The residual mixture resulting from the steam distillation was extracted with benzene. The organic layer, after being washed with water and then dried over anhydrous magnesium sulfate, was evaporated to dryness to give a solid material which was recrystallized from benzene to give a white solid with mp 211-214°. A mixed melting point with genuine 2-bromocinnamic acid was undepressed. Only 4.4 g of the 2-bromocinnamic acid was recovered but none of the desired product was obtained.

Method II: A fusion reaction using piperidine as catalyst.[40] A mixture of 4.40 g (0.0193 mol) of 2-bromocinnamic acid and 2.14 g (0.0193 mol) of thiophenol containing 0.5 ml of dry piperidine was heated to 180° for 1 hr and then the temperature was allowed to reach 230° for 15 min. The melt was allowed to cool and the taffy-like material was extracted with benzene after water was added to the cooled melt. The organic layer was washed with water, was dried over anhydrous magnesium sulfate and then the benzene was evaporated to give a sticky material which did not crystallize on standing. After much scratching, a benzene-hexane solution of the sticky substance yielded white crystals with mp 89-94°. An nmr spectrum of the white material was consistent with the predicted nmr spectrum of the desired product.

The reaction was repeated as described above except that the temperature was kept at 230° overnight. None of the desired product was obtained. Only starting material was recovered.

Again the reaction was repeated except that the heating period at 230° was only 4 hr. Again none of the desired product was obtained.

Ethyl 2-Bromocinnamate (XXXVII).-This compound was prepared by the method of Kindler.[41]

A stirred mixture of 5.00 g (0.0220 mol) of 2-bromocinnamic acid, 5.00 ml (0.0860 mol) of absolute ethanol, and 20 ml of benzene containing 1.0 ml of concentrated sulfuric acid was refluxed overnight to give a clear solution. On cooling, the solution separated into 2 layers. The organic layer was diluted with 20 ml of benzene and the layer was washed first with a 5% aqueous sodium bicarbonate solution, then with water and finally dried over anhydrous magnesium sulfate. The solvent was removed by evaporation to give a yellow-brown oil which was distilled to give 3.2 g (57%) of product with bp 174° (13 mm) (lit.[41] bp 158° (15 mm)).

Reaction of Ethyl 2-Bromocinnamate (XXXVII) with Sodium Thiolate in Dimethylformamide.-The dimethylformamide used in this experiment was dried over and distilled from calcium hydride.

To a slurry of 1.90 g of a (56.9%) mineral oil dispersion of sodium hydride (0.0450 mol) in 35 ml of dimethylformamide was added dropwise over a period of 20 min 4.95 g (0.0450 mol) of thiophenol. A clear solution resulted. The solution was warmed to 50° and then 9.60 g (0.0375 mol) of ethyl 2-bromocinnamate was added dropwise over a period of 10 min. On addition of the ester, the mixture became red-brown and a solid began to separate. The temperature was increased gradually. The mixture was stirred at 150° for 1 hr and then overnight at 90°. The demethylformamide was evaporated and then water was added to the mixture. After the mixture had been stirred for 1 hr, the solid dissolved and an oil layer resulted. The oil was extracted with hexane and the organic layer was washed with a 5% aqueous sodium bicarbonate solution, with water, and then dried over anhydrous magnesium sulfate. The solvent was evaporated and the residue was distilled to give 4.0 g of a yellow liquid with bp 160-161° (0.05 mm). An nmr spectrum of the material showed that the oil was ethyl 2-phenylthiocinnamate (XXXVIII) (*cf*. Figure 5).

Isothiachromanone (XLI).-This compound was prepared by a modification of the procedure described by C. C. Price *et*. *al*.[7]

To a rapidly stirred, gently refluxing slurry of 16.0 g of "Celite" and 32.0 g of phosphorous pentoxide in 500 ml of sodium dried benzene was added dropwise over a period of 2 hr a solution of 20.0 g (0.110 mol) of S-benzylthioglycolic acid in 200 ml of sodium dried benzene. After an additional hr of refluxing, the dark green mixture was filtered through a sintered glass funnel. The residue was then extracted twice with 200 ml portions of benzene and the benzene extracts were combined with the filtrate and washed with an aqueous 5% sodium bicarbonate solution followed by water. The organic layer was dried over anhydrous magnesium sulfate and the solvent was removed by evaporation to give a yellow residue which was distilled to give 5.3 g (31%) of a pale yellow oil with bp 95-97° 0.25 mm) (lit.[7] bp 164-165° (12mm)).

Reaction of Isothiachromanone (XLI) with Sodium Hydride and Subsequent Reaction with 1,2-Dibromomethylbenzene.-

Approximately 1 g of a 58.5% mineral oil dispersion of sodium hydride was washed thoroughly with 20-40° petroleum ether. The sodium hydride was collected under nitrogen on a sintered glass funnel. To a stirred slurry (maintained at 0°) of 0.24 g (0.010 mol) of the washed sodium hydride in 10 ml of dry tetrahydrofuran was added dropwise (to give a moderate rate of hydrogen evolution) a solution of 1.64 g (0.010 mol) of isothiachromanone in

5 ml of dry tetrahydrofuran. After being stirred for an additional 15 min, the resulting yellow-green solution was transferred to an addition funnel and added dropwise to a stirred solution of 2.64 g (0.010 mol) of 1,2-dibromomethylbenzene in 5 ml of dry tetrahydrofuran. After being stirred an additional hr, the resulting mixture was filtered to remove the light brown precipitate which had formed. Then ether was added to the filtrate and the resulting mixture was filtered. The filtrate was evaporated to give a red oil which solidified on standing. The solid was sublimed at 70° (0.1 mm) to give a yellow solid. An nmr spectrum of the yellow solid revealed that it was a mixture of isothiachromanone and 1,2-dibromomethylbenzene.

<u>3-Piperonylideneisothiachromanone</u> (XLVII).-To a stirred solution of 1.64 g (10 mmols) of isothiachromanone and 1.80 g (12 mmols) of piperonal in 35 ml of absolute ethanol was added 5 ml of 37% hydrochloric acid. The resulting yellow solution was gently refluxed for 2½ hr. The yellow-green solid which had separated was removed by filtration and the filtrate was evaporated to give a second crop of yellow-brown crystals. Both crops were recrystallized from absolute ethanol to give 2.42 g (82%) of yellow-green crystals with mp 162-164°. A sample of this material was

sublimed, recrystallized from absolute ethanol, and sublimed again to give yellow crystals with mp 161-163°.

Anal. Calcd for $C_{17}H_{12}O_3S$: C, 68.90; H, 4.08; S, 10.82 Found: C, 68.96; H, 4.15; S, 10.71.

Reaction of 3-Piperonylideneisothiochromanone (XLVII) with Methylal.[43] For 3 hr hydrogen chloride gas was bubbled through a well stirred mixture of 1.30 g (4.40 mmols) of 3-piperonylideneisothiochromanone in 9.3 g (12.2 mmols) of methylal and 8 ml of concentrated hydrochloric acid containing 2 drops of concentrated sulfuric acid. The mixture was maintained at 70-72° during the 3 hr period. Then the reaction mixture was filtered and the solid air dried to give 1.0 g of green material with mp 155-158°. One recrystallization from absolute ethanol gave yellow crystals with mp 160-162°. A mixed melting point of the yellow crystals and genuine 3-piperonylideneisothiochromanone was undepressed.

Ethyl 4-Chlorobutyrate (L).-This compound was prepared following essentially the method of Fehnel.[44]

A stirred solution of 103.6 g (1.00 mol) of 4-chlorobutyronitrile in 250 ml of absolute ethanol was cooled to 0° and saturated with dry hydrogen chloride gas.

After being stirred overnight at room temperature, the solution was refluxed for 1 hr during which time a white precipitate formed. The stirred mixture was distilled under a 30 cm Vigreux column until about 200 ml of solvent was collected. The white slurry was then diluted with 500 ml of water. The white solid dissolved and an oil which separated was removed. The aqueous layer was extracted two times with ether. The oil and the ether extracts were combined, washed with an aqueous 5% sodium bicarbonate solution and then water, and finally dried over anhydrous magnesium sulfate. The ether was removed by flash distillation and the product was distilled to give 118.5 g (79%) of a colorless liquid with bp 88° (21 mm) (lit.[44] bp 81-84° (20 mm)).

Ethyl 4-(Carbethoxymethylmercapto)-butyrate (LII).-This compound was prepared following essentially the method of Fehnel.[44]

To 315 ml of absolute ethanol stirred under dry nitrogen was added 18.0 g (0.782 mol) of sodium metal cut into small pieces. When all of the sodium had reacted, the resulting solution was cooled to 0°, and then 94.0 g (0.782 mol) of the ethyl thioglycolate was added. Over a period of 10 min, 118.0 g (0.782 mol) of ethyl 4-

chlorobutyrate was added to the above solution during which time a precipitate of sodium chloride formed. The slurry was allowed to stir for an additional 15 min at 0^o, then at room temperature overnight, and finally the mixture was refluxed for 1 hr. Nearly all of the solvent was removed by distillation under a 21 cm Vigreux column, and then the mixture was diluted with 600 ml of water. The sodium chloride dissolved and an oil separate. The lower oil layer was separated and the aqueous layer was extracted two times with ether. The oil layer and ether extracts were combined, washed once with water, and dried over anhydrous magnesium sulfate. The ether was removed by flash distillation and the product was distilled to give 139 g (77%) of a colorless liquid with bp 144^o (4 mm) (lit.[44] bp $139\text{-}142^o$ (4 mm)).

<u>2-Carbethoxytetrahydrothiapyran-3-one</u> (LIII).-This compound was prepared following the method of Fehnel.[44]

To a two liter three neck flask equipped with a stirrer, condenser, inlet for nitrogen, and an inlet for dry ether was added 200 ml of absolute ethanol under nitrogen and then 24.0 g (1.04 mol) of sodium metal cut into small pieces. When all of the sodium had reacted, the solvent was removed by vacuum distillation. The resulting paste was then dried in vacuo at about 50° for 2 hr so that the sodium ethoxide became a dusty white powder. The sodium ethoxide was cooled to 0° and then about 600 ml of ether dried over sodium ribbon was distilled into the flask. The slurry was stirred rapidly and 122.0 g (0.520 mol) of ethyl 4-(carbethoxymethylmercapto) butyrate was added dropwise to the slurry over a period of 40 min. The slurry gradually became a thick paste. The paste was stirred for an additional hour and then was hydrolyzed with a mixture of 95 ml of glacial acetic acid in 600 ml of crushed ice and water. The aqueous layer was separated and extracted with ether until the ether layer no longer gave a blue color with ferric chloride in ethanol. The ether layers were combined, washed with water and then dried over anhydrous magnesium sulfate. The ether was removed by flash distillation and the acetic acid was removed by distillation at slightly reduced pressure (150 mm). The residue was distilled to give 75.7 g (77%) of a colorless liquid with bp 119-121° (4 mm) (lit.[44] bp 117-120° (4 mm)).

Tetrahydrothiapyran-3-one (XLVIII).-This compound was prepared following essentially the method of Fehnel.[44]

A stirred mixture of 62.0 g (0.330 mol) of 2-carbethoxytetrahydothiopyran-3-one in 425 ml of 5% sulfuric acid was refluxed for 5 hr. The mixture was cooled and then extracted with ether. The aqueous layer was then treated with 35 g of sodium acetate followed by dropwise addition of a 50% sodium hydroxide solution until the pH was about 7. An oil which separated was extracted with ether and then added to the other ether extract. The ether extracts were washed with water and dried over anhydrous magnesium sulfate. The ether was removed by distillation, and the residue was distilled to give 24.6 g (64%) of a colorless oil with bp 76-78° (3.75 mm) (lit.[44] bp 77-80° (5 mm)).

<u>4-Phenoxybutyl Bromide</u> (LVII).-This compound was prepared by the method of Peyron and Peyron.[45]

To 600 ml of absolute methanol was added 30.5 g (1.33 mol) of sodium metal cut into small pieces. After a solution of 125 g (1.33 mol) of phenol in 150 ml of absolute methanol was added to the sodium methoxide solution, a solution of 431.8 g (2.0 mols) of 1,4-dibromobutane in 250 ml of absolute methanol was added dropwise over a period of 30 min. The resulting solution was then stirred and refluxed for 2 hr after which time the solvent was removed by slow distillation under a 30 cm Vigreux column. The residue was poured into water and extracted with ether. The layers were separated and the ether layer was washed with a 5% sodium carbonate solution, water, and the ether layer was dried over anhydrous magnesium sulfate. The ether was removed by flash distillation to give a mixture which was distilled to give 186.9 g of 1,4-dibromobutane as forerun with bp 30-108° (1.15 mm). The main fraction distilled at 108-110° (1.15 mm) to give 133.2 g of product (lit.[45] bp 156° (18 mm)) and the residue distilled at 160° (1.15 mm) to give 33.8 g of 1,4-diphenoxybutane (lit.[45] bp 190 (10 mm)).

4-Phenoxybutyraldehyde (LIV).-The compound was prepared by a modification of the method of Kornblum.[46]

To 75 ml of dimethylsulfoxide which had been refluxed with and distilled from calcium hydride was added 10.0 g (0.119 mol) of sodium bicarbonate. Nitrogen was bubbled through the stirred slurry and then 22.7 g (0.100 mol) of 4-phenoxybutyl bromide was added and the resulting mixture was heated at 100° for 1 hr. Water was added to the reaction mixture which was extracted with ether. The layers were separated and the ether layer was dried over anhydrous magnesium sulfate. The ether was evaporated and the residue distilled to give 10.6 g (65%) of product with bp 104-114° (1.5 mm). The product was redistilled to give a colorless liquid with bp 114-116^{o} (1.5 mm). A semicarbazone of the colorless liquid was prepared. The mp of the white powder was 117-119^{o} (lit.[57] mp 118^{o}). An infrared spectrum (neat) of the liquid product exhibited bands at 3015 medium (aromatic C-H), 2915,2857 strong (aliphatic C-H), 2717 weak (aldehydic C-H), 1724 medium $({}^{H}{>}C{=}O)$ as well as strong bands at 1600,1492,1238,1036,747, and 685 cm^{-1}

Reaction of 4-Phenoxybutyraldehyde (LIV) with Tetrahydrothiapyran-3-one (XLVIII).-To a solution of 1.16 g (0.010 mol) of tetrahydrothiapyran-3-one and 1.97 g (0.012 mol) of 4-phenoxybutyraldehyde in 35 ml of absolute ethanol was added with stirring 5 ml of concentrated hydrochloric acid. The solution, which was gently refluxed for 1 hr, gradually turned dark brown in color. The reaction mixture was then extracted with methylene chloride and the methylene chloride layer was washed first with a 5% aqueous sodium bicarbonate solution and then with water. The methylene chloride layer was dried over anhydrous magniesum sulfate and the methylene chloride was removed by evaporation to give a dark residue which gave 1.0 g of a colorless liquid with bp 95-100^{o} (1.0 mm); ir (neat) 3015 medium, 2915,2857 strong, 2717 weak, 1724 medium, and strong bands at 1600,1492,1238,1036,747 and 685 cm^{-1} The colorless liquid was recovered 4-

phenoxybutyraldehyde.

Reaction of Tetrahydrothiapyran-3-one (XLVIII) with Piperonal (XLVI).-To a solution of 1.16 g (0.010 mol) of tetrahydrothiapyran-3-one and 1.81 g (0.012 mol) of piperonal in 35 ml of absolute ethanol was added with stirring 5 ml of concentrated hydrochloric acid. The resulting solution was refluxed for 1 hr to give an orange solid. The reaction mixture was cooled, added to water, and then extracted with methylene chloride. The layers were separated and the organic layer was washed first with a 5% aqueous sodium bicarbonate solution and then with water. The organic layer was dried over anhydrous magnesium sulfate and the solvent evaporated to give an orange solid with mp 130-135°. One recrystallization from absolute ethanol raised the mp of 2,4-dipiperonylidenetetrahydrothiapyran-3-one to 163-165°.

Anal. Calcd for $C_{21}H_{16}O_5S$: C, 66.30; H, 4.24; S, 8.43. Found: C, 66.18; H, 4.06; S, 8.33.

4-Bromobutyl Acetate (LX).-To 7.21 g (0.100 mol) of tetrahydrofuran cooled to 3° in an ice bath was added dropwise with stirring 12.3 g (0.100 mol) of acetyl bromide. When the addition was complete, the resulting solution was warmed to 65° for 2 hr. The crude material was distilled to give 16.3 g (84%) of product with bp 94-96° (20 mm). Redistillation gave product with bp 92° (20 mm); ir (neat) 2941 medium (aliphatic C-H), 1730 strong (ester carbonyl), 1433,1383 medium, 1362,1234,1036 strong, 943,870,745 weak cm^{-1}.

Reaction of 4-Bromobutyl Acetate (LX) with Tetrahydrothiapyran-3-one (XLVIII).-To a well stirred mixture of 0.375 g (15.6 mmols) of sodium hydride in 10 ml of tetrahydrofuran distilled from calcium hydride was added dropwise over a period of 45 min a solution of 1.80 g (15.5 mmols) of tetrahydrothiapyran-3-one in 10 ml of dry tetrahydrofuran. Then a solution of 12.1 g (62.0 mmols) of 4-bromobutyl acetate in 10 ml of tetrahydrofuran was added over a period of 1 hr to give a white precipitate. The resulting mixture was gently refluxed overnight. After the mixture was cooled, ether was added and then water. The layers were separated and the aqueous layer was extracted with ether, the ether layers were combined, washed with water, and the ether layer was dried over anhydrous magnesium sulfate. The ether was removed by distillation and the residue was distilled to give 9.1 g of material with bp 101-104° (13 mm); ir (neat) 2941 medium (aliphatic C-H), 1730 strong ester carbonyl), 1433,1383 medium, 1362,1234,1036 strong, 943,870,745 weak

cm^{-1}. The bp of 4-bromobutylacetate was 92° (20 mm). Only an intractable tar remained as a residue after the distillation.

2H-3,4-Dihydro-5-morpholinothiapyran (LXI).-A solution of 10.0 g (0.086 mol) of tetrahydrothiapyran-3-one and 15.0 g (0.172 mol) of morpholine in 250 ml of benzene was refluxed overnight. A Dean Stark trap was used to collect the water azeotroped from the reaction. Then the material was distilled at reduced pressure to remove the benzene and part of the excess morpholine. The residue was distilled to give 14.2 g (84%) of product with bp 105-108° (0.1 mm); nmr (C_6D_6) δ 4.92 (s,1,H-6), 3.58 (m,4,2-CH_2- adjacent to nitrogen in the morpholino moiety), 2.57 (m,6,2-CH_2- adjacent to nitrogen in the morpholino moiety and 2H-4 protons), 1.97 (m,4,H-2 and H-3 protons) ppm.

Reaction of 2H-3,4-Dihydro-5-morpholinothiapyran (LXI) with 3-Carbomethoxypropionyl Chloride (LXII).-The experiment was conducted using a modification of a method of Hunig, Lucke, and Brenniger.[47]

To a solution of 10.0 g (0.054 mol) of 2H-3,4-dihydro-5-morpholinothiapyran and 5.45 g (0.054 mol) of triethyl amine in 35 ml of dry chloroform at 35° was added over a period of 30 min a solution of 8.15 g (0.054 mol) of 3-carbomethoxypropionyl chloride in 10 ml of dry chloroform. The resulting orange-yellow mixture was stirred for 3 hr and then the solid triethyl amine hydrochloride was removed by filtration. The filtrate was distilled at reduced pressure to remove the chloroform and the residue was distilled to give an oily solid with bp 185° (0.5 mm). The oily material was dissolved in a solution of 25 ml of methanol and 10 ml of water containing 1.0 g of p-toluenesulfonic acid and then stirred for 1 hr. The solvent was then evaporated and the residue extracted into ether. The ether layer was dried over anhydrous magnesium sulfate, and then the ether was evaporated to give a nearly colorless oil. An infrared spectrum of the oil was nearly identical with the infrared spectrum of genuine tetrahydrothiapyran-3-one. Evaporation of the aqueous layer gave a liquid, the infrared spectrum of which was nearly identical with infrared spectrum of dimethylsuccinate.

Reaction of 2-Carbethoxytetrahydrothiopyran-3-one (LIII) with Sodium Hydride and Subsequent Reaction with Ethyl 4-Bromobutyrate (LXIV).-A few grams of a 58.5% mineral oil dispersion of sodium hydride were washed thoroughly with 20-40° petroleum ether. The sodium hydride was collected under nitrogen on a sintered glass funnel. To 30 ml of dry tetrahydrofuran was added with stirring 1.47 g (0.0612 mol) of the washed sodium hydride. To the resulting slurry was added a solution of 10.0 g (0.0532 mol) of 2-carbethoxytetrahydrothiopyran-3-one in 10 ml of dry tetrahydrofuran. The addition rate was regulated to give a moderate rate of hydrogen evolution. After all of the keto-ester was added, the slurry was stirred for an additional 90 min. Then a solution of 10.4 g (0.0532 mol) of ethyl 4-bromobutyrate in 10 ml of dry tetrahydrofuran was added to the slurry over a period of 15 min. After stirring overnight, the mixture was filtered. Ether was added to the filtrate and then about 25 ml of glacial acetic acid was added. Water was added until two distinct layers formed and then the system was extracted twice with ether. The ether extracts were combined and dried over anhydrous magnesium sulfate. The ether was removed by flash distillation and the residue was distilled at 30 mm to remove any low boiling material. The remaining oil was distilled to give 2.75 g of a pale yellow liquid with bp 119-122^{o} (4 mm). An infrared spectrum of the liquid was superimposible on the spectrum of genuine 2-carbethoxytetrahydrothiopyran-3-one (lit.[44] bp 117-120^{o} (4 mm)).

1,9-Diphenoxy-5-Nonanol (LXVI).-This compound was prepared by the method of Eastman and Kritchevsky.[48]

To a well stirred mixture of 14.2 g (0.585 mol) of magnesium turnings in 100 ml of ether was added dropwise a solution of 133.2 g (0.585 mol) of 4-phenoxybutyl bromide in 250 ml of ether at such a rate that the ether refluxed gently. To the resulting Grignard reagent, which was stirred for an additional hr and then cooled in an ice bath, was added over a period of 2 hr a solution of 21.0 g (0.284 mol) of ethyl formate in 60 ml of ether. The reaction mixture was stirred for an additional 30 min and then 40 ml of water was added dropwise, followed by a solution of 34 g of concentrated sulfuric acid in 160 ml of water. The layers were separated and the water layer was extracted with ether. The ether layers were combined and washed with water and then the ether layer was dried over anhydrous potassium carbonate. The ether was removed by evaporation to give an oil which was twice recrystallized from n-hexane to give 70 g (75%) of white crystals with mp 56-59° (lit.[48] mp 58-59°).

1,9-Diphenoxy-5-Bromononane (LXVII).-This compound was prepared by the method of Eastman and Kritchevsky.[48]

A mixture of 46.0 g (0.140 mol) of 1,9-diphenoxy-5-nonanol and 46.0 g (0.170 mol) of phosphorus tribromide was dissolved in 50 ml of carbon disulfide and the resulting solution was allowed to stand for 1 week. The carbon disulfide was removed by evaporation, the residue was decomposed by the addition of ice water, and the product was extracted into ether and the ether layer was dried over anhydrous magnesium sulfate. The ether was removed by evaporation to give an oily product which was recrystallized from methanol to give 27.8 g (51%) of material with mp 41-43° (lit.[48] mp 45.4-46.8°).

2-Iodoethanol (LXIX).-This compound was prepared following an appropriately modified Organic Synthesis[58] procedure for 2-bromoethanol.

To 384 g of 50% hydriodic acid (1.50 mol of HI) cooled to 0° in a salt-ice bath was added over a period of 1 hr 50.1 g (1.14 mol) of ethylene oxide. After the resulting solution was allowed to stir at less than 10° for an additional hr, 30 g of anyhdrous sodium carbonate was added to the reaction. Then 33 g of anhydrous sodium sulfate was added with stirring to the two phase system. Stirring was discontinued and the two layers were separated. The lower organic layer was filtered to remove any excess sodium sulfate, while the aqueous layer was extracted twice with ether and then the ether extracts were combined with the oil layer and dried overnight over anhydrous sodium sulfate. The ether was removed by distillation under a 21 cm Vigreux column and the residue was distilled to give 170 g (87%) of a pale red product with bp 72-74^{o} (25 mm) (lit.[59] bp 85^{o} (25 mm)).

Reaction of 2,5-Diphenyl-1,4-dithiin (VI) with 2-Iodoethanol (LXIX) and Mercuric Iodide.-The procedure used for this reaction was that of van der Veen.[36]

A stirred mixture of 2.68 g (0.010 mol) of 2,5-diphenyl-1,4-dithiin, 6.88 g (0.040 mol) of 2-iodoethanol, and 4.54 g (0.010 mol) in 3 ml of absolute ethanol was refluxed for 1 hr. The resulting solution was cooled to room temperature and then poured into 20 ml of absolute ethanol to give a purple solid which was collected and recrystallized from absolute ethanol. The material had a mp 113-115^{o}. A mixed melting point with genuine 2,5-diphenyl-1,4-dithiin was undepressed. Evaporation of the ethanol into which the reaction mixture had been poured yielded only tar.

Reaction of 2,5-Diphenyl-1,4-dithiin (VI) with 2-Iodoethanol (LXIX) and Silver 2,4,6-Trinitrobenzenesulfonate Acetonitrile Complex (XXVI).-To a stirred solution of 0.52 g (1.94 mmols) of 2,5-diphenyl-1,4-dithiin and 1.72 g (10.0 mmols) of 2-iodoethanol in 10 ml of methylene chloride and

5 ml of nitromethane was added a warm solution (50°) of 1.00 g (1.91 mmol) of AgTNBS·$3CH_3CN$ in 10 ml of nitromethane and 0.5 ml of acetonitrile. (The reaction vessel was wrapped with aluminum foil to protect the reaction from light). The reaction mixture was allowed to stir for 18 hr, and then the silver iodide precipitate was removed by filtration. The precipitate was washed with ether and allowed to air dry to give 0.43 g (97%) of silver iodide. Then with rapid stirring, the filtrate was diluted to about 200 ml with anhydrous ether. Only a sticky solid precipitated. The liquid was decanted and the sticky material was dissolved in 10 ml of acetonitrile. A lighter brown sticky solid again precipitated on dilution with 100 ml of ether.

Sodium Phenacylthiosulfate Monohydrate (LXXV).-This compound was prepared by the method of Baker and Barkenbus.[12]

A rapidly stirred mixture of 61.6 g (0.398 mol) of phenacyl chloride and 100 g (0.404 mol) of sodium thiosulfate pentahydrate in 60 ml of water was heated at 60° for 30 min during which time solution occurred. On cooling, the solution yielded white crystals which were recrystallized once from 95% ethanol to give 80 g (74%) of product.

2,5-Diphenyl-1,4-dithiin (VI).-This compound was prepared by a modification of the method Baker and Barkenbus.[12]

A well stirred slurry of 109 g (0.20 mol) of sodium phenacylthiosulfate monohydrate in 360 ml of absolute ethanol was warmed to gentle reflux. The hydrogen chloride gas was bubbled slowly through the slurry until the slurry was saturated with hydrogen chloride gas. The reaction time was 3 to 4 hr. The reaction mixture was cooled and filtered. The material obtained was carefully extracted into glacial acetic acid warmed to 100°. The acetic acid solution was cooled to give yellow crystals which were recrystallized once from absolute ethanol to give 44.5 g (83%) of product with mp 112-114° (lit.[12] mp 115-117°); uv max (MeCN) 261 $m\mu$ ($\log\epsilon$ 4.37), 308 (3.94), 340 (3.00); nmr ($CDCl_3$)δ 7.50 (m,10,phenyl), 6.58 (s,2,H-3 and H-6) ppm; nmr (DMSO-d_6)δ 7.55 (m,10,phenyl), 6.75 (s,2,H-3 and H-3) ppm.

<u>3-Bromo-2,5-diphenyl-1,4-dithiin</u> (LXXXIV).-This compound was prepared by the method of Parham *et*. *al*.[52]

To a solution of 12.0 g (0.0445 mol) of 2,5-diphenyl-1,4-dithiin in 600 ml of acetic anhydride was added dropwise a solution of 7.20 g (0.0450 mol) of bromine in 30 ml of glacial acetic acid. After the addition was complete, the solution was allowed to stir for an additional 10 min. Then the solution was poured into ice water and stirred for 1 hr.

The crude yellow solid was filtered, washed with water, and then recrystallized from 95% ethanol to give 12.0 g (78%) of pale yellow crystals with mp 80-83° (lit.[52] mp 85-86°); uv max (MeCN) 252 $m\mu$ (logϵ 4.31), 311 (3.76) sh; nmr (CD_3CN)δ 7.50 (m,10,phenyl), 6.98 (s,1,H-6) ppm; nmr (DMSO-d_6)δ 7.50 (m,10,phenyl), 7.32 (s,1,H-6) ppm.

3-Nitro-2,5-diphenyl-1,4-dithiin (LXXXVI).-This compound was prepared by the method of Parham and Traynelis.[54]

A 10M nitrating solution was prepared by mixing 31.6 ml of concentrated nitric acid (0.5 mol), 0.5 g of urea, and diluting the solution to 50 ml with glacial acetic acid.

To a solution of 5.00 g (0.186 mol) of 2,5-diphenyl-1,4-dithiin in 250 ml of acetic anhydride at room temperature was added 2 ml (0.020 mol) of the nitrating solution. The resulting red mixture was allowed to stir at room temperature for 5 min and then the solution was poured into an excess of ice water. An oil which solidified on stirring for 1 hr separated. The solid was collected by filtration and was washed well with water and then air dried. Recrystallization of the crude material from ethyl acetate gave 3.9 g (67%) of deep red needles with mp 134-136° dec. (lit.[54] mp 131-132° dec.); uv max (MeCN) 245 $m\mu$ (logϵ 4.23), 300 (4.08), 440 (2.94); nmr ($CDCl_3$)δ 7.42 (m,10,phenyl), 6.67

(s,1,H-6) ppm; nmr (DMSO-d_6)δ 7.52 (m,10,phenyl), 7.37 (s,1,H-6) ppm.

2,4,6-Trinitrobenzenesulfonic Acid Dihydrate (XXVIII).-This compound was prepared following the method of Pettitt and Helmkamp.[31]

To 20.0 g (0.081 mol) of picryl chloride dissolved in 200 ml of absolute ethanol was added 20.0 g (0.105 mol) of anhydrous sodium meta-bisulfite. The resulting mixture was vigorously stirred and heated for 3 hr under reflux and then cooled below 5° and filtered. The crude sodium salt was washed with four 20 ml portions of cold, absolute ethanol to give a tan solid which was air dried for 1 hr. The sodium salt was mixed with 60 ml of acetone and then 20 ml of concentrated hydrochloric acid was added over a 2 min period. The precipitated sodium chloride was removed by filtration and was washed with two 10 ml portions of acetone. The combined filtrates were evaporated to give a yellow solid which was recrystallized from acetone-chloroform to give 24.9 g (94%) of a tan solid with mp 80-85° (resolidification above 140°) and 193°-195° (lit.[31] mp 85-87° (resolidification at 125-135°) and 193-195°).

Silver 2,4,6-Trinitrobenzenesulfonate Acetonitrile Complex

($AgTNBS \cdot 3CH_3CN$) (XXVI).-This compound was prepared following the method of Pettitt and Helmkamp.[31]

A solution of 7.30 g (0.0430 mol) of silver nitrate in 15 ml of warm water was added with stirring to 10.7 g (0.0325 mol) of 2,4,6 trinitrobenzenesulfonic acid dihydrate in 15 ml of warm water. The resulting tan mixture was cooled and the product was collected by filtration using a sintered glass funnel. The solid was twice slurried with 40 ml of 95% ethanol and once with 40 ml of anhydrous ether. The crude product was then dissolved in the minimum amount of boiling acetonitrile. Anhydrous ether was added to the boiling solution until the solution became slightly turbid. On cooling, the solution yielded 13.9 g (82%) of pale pink solid with mp 86-89° (resolidification above 180°) and 344° dec. (lit.[31] mp 88-89° (resolidification 170-180°) and 355-358° dec.). Based on the nuclear magnetic resonance spectrum and equivalent weight determination of the material recrystallized from acetonitrile-ether, three molecules of acetonitrile are contained in each molecule of the silver salt.

Silver Perchlorate Acetonitrile Complex ($AgClO_4 \cdot 4CH_3CN$) (LXXVII).-To a solution of 34.6 g (0.204 mole) of silver nitrate in 75 ml of acetonitrile heated nearly to boiling was added a boiling solution of 25.0 g (0.204 mol) of anhydrous sodium perchlorate in 100 ml of acetonitrile. On combination of the two solutions, a white precipitate of sodium nitrate formed immediately. The resulting mixture was cooled to room temperature and then the precipitate was removed by filtration. The precipitate was slurried with 50 ml of acetonitrile, filtered again, washed with ether, and dried to give 17.0 g (98%) of sodium nitrate. The filtrates were combined and sufficient ether was added to precipitate the silver salt. The silver salt was collected by filtration and dried in a desiccator over Drierite to give 58.0 g (77%) of product with mp 78-82° with resolidification above 270°.

Anal. Calcd for $C_8H_{12}AgClN_4O_4$: Ag, 29.03. Found: Ag, 28.94.

Silver Tetrafluoroborate Acetonitrile Complex ($AgBF_4 \cdot 4CH_3CN$) (LXXVIII).-To a well stirred slurry of 12.2 g (0.112 mol) of anhydrous sodium tetrafluoroborate in 500 ml of acetonitrile was added a solution of 19.0 g (0.112 mol) of silver nitrate in 200 ml of acetonitrile. (The reaction vessel was covered with aluminum foil to protect the reaction from light). After the slurry was stirred overnight, the sodium nitrate was removed by filtration and was washed with acetonitrile first and then ether. About 500 ml of acetonitrile was evaporated from the combined filtrates. Ether was added to the residual solution in order to precipitate the silver salt. The salt was collected by filtration and then dissolved in the least amount of acetonitrile needed to effect solution. The cloudy solution was clarified by filtration and the ether was added once again to precipitate the silver salt. The silver salt was collected by filtration and dried in a desiccator over Drierite to give 20.3 g (75%) of product.

Anal. Calcd for $C_8H_{12}AgBF_4N_4$: Ag, 30.06. Found: Ag, 29.98.

Dibenzylethylsulfonium 2,4,6-Trinitrobenzenesulfonate (XXX).- To a stirred solution of 0.30 g (1.97 mmol) of benzylethyl sulfide and 1.71 g (10 mmols) of benzyl bromide in 10 ml of methylene chloride and 5 ml of nitromethane was added dropwise over a period of 20 min a solution of 1.00 g (1.91 mmol) of AgTNBS·3CH_3CN in 10 ml of nitromethane. A yellow precipitate began to form almost immediately. The reaction mixture was allowed to stir for an additional 45 min after which time the yellow solid was removed by filtration. Then ether was added to the filtrate until the cloud point was reached. The off-white crystals which formed were filtered, washed with ether, and dried to give 0.8 g (79%) of material with mp about 160°. Three recrystallizations from absolute ethanol-nitromethane gave analytical material with mp 181-182° dec. Nmr (CD_3CN)δ 8.57 (s,2,TNBS$^-$), 7.47 (s,10, phenyl), 4.58 (s,4,benzyl CH_2), 3.18 (q,2,J=7.0 Hz, ethyl CH_2), 1.22 (t,3,J=7.0 Hz, CH_3) ppm.

Anal. Calcd for $C_{22}H_{21}N_3O_9S_2$: C, 49.34; H, 3.95; N, 7.85; S, 11.97. Found: C, 49.44; H, 4.21; N, 7.77; S, 12.02.

Benzyl-o-bromomethylbenzylethylsulfonium 2,4,6-Trinitrobenzenesulfonate (XXXI).-To a stirred solution of 0.30 g (1.97 mmol) of benzylethylsulfide and 2.64 g (10 mmols) of 1,2-dibromomethyl benzene in 10 ml of methylene chloride and 5 ml of nitromethane was added dropwise over a period of 20 min a solution of 1.00 g (1.91 mmol) of AgTNBS·3CH_3CN in 10 ml of nitromethane. A yellow precipitate began to form almost immediately. The reaction mixture was allowed to stir for an additional 45 min after which time the yellow solid was removed by filtration. Then ether was added to the filtrate until the cloud point was reached. The off-white crystals which formed were filtered, slurried with ether, filtered, and dried to give 0.9 g (75%) of material with mp of about 130°. Two recrystallizations from acetronitrileether gave analytical material with mp 142-144° dec. Nmr (CD_3CN)δ 8.57 (s,2,TNBS$^-$), 7.50 (s,9,phenyl), 4.70 (s,4, benzyl CH_2 adjacent to sulfonium center), 4.62 (s,2, benzyl CH_2-Br), 3.35 (q,2,J=7.0 Hz, ethyl CH_2), 1.23 (t,3, J=7.0 Hz, CH_3) ppm.

Anal. Calcd for $C_{23}H_{22}BrN_3O_9S_2$: C, 43.95; H, 3.53; N, 6.69; S, 10.20; Br, 12.72. Found: C, 43.85; H, 3.41; N, 6.71; S, 10.36; Br, 12.80.

1-Methyl-2,5-diphenyl-1,4-dithiinium Triiodomercurate (LXXVI).- This reaction was conducted following essentially the procedure of J. van der Veen[36] for the preparation of phenyl dimethylsulfonium triiodomercurate.

To a stirred solution (heated to reflux) of 2.68 g (0.010 mol) of 2,5-diphenyl-1,4-dithiin in 5.0 ml (0.080 mol) of methyl iodide was added 4.54 g (0.010 mol) of mercuric iodide. The red mercuric iodide was almost immediately decolorized and the color of the solution gradually changed from yellow to orange. After being heated for 40 min, the resulting solution was allowed to stand overnight. The reaction mixture was treated with 200 ml anhydrous ether to give 7.25 g (84%) of a yellow solid with mp 89-94° dec. The crude material was then recrystallized from acetone-absolute ethanol to give pale yellow crystals with mp 96-97° dec; nmr (DMSO-d_6)δ 8.77 (s,1,H-3), 7.73 (m,10,phenyl), 6.92 (s,1,H-6), 3.08 (s,3,CH_3) ppm.

Anal. Calcd for $C_{17}H_{15}HgI_3S_2$: C, 23.61; H, 1.75; Hg, 23.20; I, 44.03; S, 7.41. Found: C, 23.59; H, 1.96; Hg, 23.38; I, 43.80; S, 7.23.

1-Methyl-2,5-diphenyl-1,4-dithiinium 2,4,6-Trinitrobenzenesulfonate (LXXIX).-To a stirred solution of 0.52 g (1.94 mmol) of 2,5-diphenyl-1,4-dithiin and 1.42 g (10.0 mmols) of methyl iodide in 10 ml of methylene chloride and 5 ml of nitromethane was added a warm solution (50°) of 1.00 g (1.91 mmol) of AgTNBS$\cdot$3CH_3CN in 10 ml of nitromethane and 0.5 ml of acetonitrile. (The reaction vessel was wrapped with aluminum foil to protect the reaction from light). The reaction mixture was allowed to stir for 18 hr, and then the silver iodide precipitate was removed by filtration. The precipitate was washed with ether and allowed to air dry to give 0.44 g (98%) of silver iodide. Then, with rapid stirring, the filtrate was diluted to about 200 ml with anhydrous ether. The precipitate was collected by filtration, washed with anhydrous ether, and air dried to give 0.97 g (88%) of a buff solid. One recrystallization from absolute ethanol-acetonitrile gave buff crystals with mp 165° dec.

On heating the buff crystals several color changes were noted as follows: buff solid became orange-red above 100° with increasing redness up to 150°; from 150-159° the crystals became green with slight shrinkage at 162°; color became darker with softening and finally there was sharp decomposition at 165°; nmr (DMSO-d_6)δ 8.87 (s,2,TNBS$^-$), 8.75 (s,1,H-3), 7.68 (m,5,phenyl), 6.90 (s,1,H-6), and 3.07 (s,3,CH_3) ppm.

Anal. Calcd for $C_{23}H_{17}N_3O_9S_3$: C, 47.99; H, 2.98; N, 7.30; S, 16.71. Found: C, 47.89; H, 2.90; N, 7.18; S, 16.66.

1-Methyl-2,5-diphenyl-1,4-dithiinium Perchlorate (LXXX).- To a stirred solution of 0.78 g (2.90 mmols) of 2,5-diphenyl-1,4-dithiin and 2.00 g (14.1 mmols) of methyl iodide in 10 ml of methylene chloride and 5 ml of nitromethane was added a solution of 0.95 g (2.56 mmols) of $AgClO_4 \cdot 4CH_3CN$ in 10 ml of nitromethane. (The reaction vessel was wrapped with aluminum foil to protect the reaction from light). The reaction mixture was allowed to stir for 18 hr, and then the silver iodide precipitate was removed by filtration. The precipitate was washed with ether and allowed to air dry to give 0.60 g (93%) of silver iodide. Then with rapid stirring, the filtrate was diluted to about

200 ml with anhydrous ether. The precipitate was collected by filtration, washed with anhydrous ether, and air dried to give 0.80 g (82%) of white crystals with mp 164-165° dec. The crude product was recrystallized from methylene chloride-acetonitrile-ether to give a white product with mp 164-165° dec.; nmr (DMSO-d_6)δ 8.75 (s,1,H-3), 7.73 (m,10,phenyl), 6.90 (s,1,H-6), 3.07 (s,3,CH_3) ppm; nmr (CF_3CO_2H)δ 8.17 (s,1,H-3), 7.67 (m,10,phenyl), 6.57 (s,1, H-6), 3.03 (s,3,CH_3) ppm; nmr (CD_3CN)δ 8.28 (s,1,H-3), 7.70 (m,10,phenyl), 6.58 (s,1,H-6), 2.93 (s,3,CH_3) ppm.

Anal. Calcd for $C_{17}H_{15}ClO_4S_2$: C, 53.33; H, 3.95; Cl, 9.26; S, 16.75. Found: C, 53.13; H, 3.86; Cl, 9.14; S, 16.89.

1-Methyl-2,5-diphenyl-1,4-dithiinium Tetrafluoroborate (LXXXI).-To a stirred solution of 0.81 g (3.02 mmols) of 2,5-diphenyl-1,4-dithiin and 2.14 g (15.0 mmols) of methyl iodide in 10 ml of methylene chloride and 5 ml of nitromethane was added a solution of 1.06 g (2.97 mmols) of $AgBF_4 \cdot 4CH_3CN$ in 15 ml of nitromethane. Conditions and work up are similar to methyl iodide - $AgClO_4 \cdot 4CH_3CN$ case. The silver iodide obtained weighed 0.68 g (98%). The yellow product collected amounted to 0.91 g (83%) with mp 163-164° dec. Treatment of an acetonitrile solution of the crude product with Norit A (neutral) with subsequent dilution of the filtrate with ether resulted in a white product. Recrystallization from acetonitrile-ether gave white crystals with mp 163-164° dec.; uv max (MeCN) 272 $m\mu$ ($\log\epsilon$ 4.43), 312 (3.94) sh; nmr (CF_3CO_2H) δ 8.15 (s,1,H-3), 7.65 (m,10,phenyl), 6.55 (s,1,H-6), 3.02 (s, 3,CH_3) ppm; nmr (CD_3CN) δ 8.35 (s,1,H-3), 7.72 (m,10, phenyl), 6.65 (s,1,H-6), 2.98 (s,3,CH_3) ppm.

Anal. Calcd for $C_{17}H_{15}BF_4S_2$: C, 55.15; H, 4.08; F, 20.53; S, 17.32. Found: C, 55.11; H, 4.10; F, 20.25: S, 17.55.

1-Ethyl-2,5-diphenyl-1,4-dithiinium 2,4,6-Trinitrobenzenesulfonate (LXXXII).-Procedure for this preparation is similar to the methyl iodide case. Because the product was very sensitive to light, the workup of the reaction and the subsequent purification were done in the dark.

The yield was 1.30 g (58%) of buff crystals. The crude product was dissolved in boiling acetonitrile, treated with Norit A (neutral), filtered, and then the filtrate was diluted with excess ether to obtain the product. The subsequent recrystallizations were done using acetonitrile-ether. The product had a mp of 176-177° dec. with color changes similar to the methyl case but occurring 10° later than the methyl case. This ethyl compound showed nmr (DMSO-d_6) δ 8.88 (s,2,TNBS$^-$), 8.80 (s,1,H-3), 7.72 (m,10,phenyl), 6.97 (s,1,H-6), 3.58 (q,2,J=7.5 Hz, CH_2), and 1.35 (t,3,J=7.5 Hz, CH_3) ppm.

Anal. Calcd for $C_{24}H_{19}N_3O_9S_3$: C, 48.89; H, 3.25; N, 7.13; S, 16.31. Found: C, 49.04; H, 3.38; N, 7.30; S, 16.31.

1-Ethyl-2,5-diphenyl-1,4-dithiinium Perchlorate (LXXXIII).- Procedure for this preparation is similar to the methyl iodide case except that 22.0 g (141 mmols) of ethyl iodide was used in the reaction. The yield was 0.66 g (66%) of a yellow solid with a melting point of 140° dec. The crude product was dissolved in boiling acetonitrile, treated with Norit A (neutral), filtered, and then the filtrate was diluted with excess ether to obtain the product. The subsequent recrystallizations were done using methylene chloride-ether to give a product with mp 147-148° dec.; nmr δ (CF_3CO_2H) 8.17 (s,1,H-3), 7.65 (m,10,phenyl), 6.50 (s,1,H-6), 3.58 (q,2,J=7.5 Hz, CH_2), 1.50 (t,3,J=7.5 Hz CH_3) ppm; nmr δ (CD_3CN) 8.32 (s,1,H-3), 7.67 (m,10,phenyl), 6.60 (s,1, H-6), 3.48 (q,2,J=7.5 Hz, CH_2), 1.37 (t,3,J=7.5 Hz, CH_3) ppm.

Anal. Calcd for $C_{18}H_{17}ClO_4S_2$: C, 54.47; H, 4.32; Cl, 8.93; S, 16.16. Found: C, 54.27; H, 4.29; Cl, 8.75;

S, 16.02.

1-Methyl-3-bromo-2,5-diphenyl-1,4-dithiinium Perchlorate (LXXXV).-To a stirred solution of 2.28 g (6.55 mmols) of 3-bromo-2,5-diphenyl-1,4-dithiin and 9.22 g (65.0 mmols) of methyl iodide in 20 ml of methylene chloride and 10 ml of nitromethane was added a solution of 2.35 g (6.50 mmols) of $AgClO_4$ $4CH_3CN$ in 20 ml of nitromethane. (The reaction vessel was wrapped with aluminum foil to protect the reaction from light). The reaction mixture was allowed to stir for 18 hr, and then the yellow precipitate was removed by filtration. The precipitate was washed with ether and allowed to air dry to give 2.45 g (161% based on theroetical silver iodide) of yellow solid. The yellow solid was slurried in hot acetonitrile. The mixture was filtered to give 1.50 g (99%) of silver iodide (after air drying) and a clear colorless filtrate which was rapidly stirred and diluted with excess ether to give 0.85 g (31%) of white crystals with mp 190° dec. The white solid was recrystalized from acetonitrile-ether to give a glistening white crystaline solid with mp 189° dec.; uv max (MeCN) 272 mμ (logϵ 4.37); nmr (DMSO-d_6)δ 7.77 (m,10,phenyl), 7.08 (s,1, H-6), 3.27 (s,3,CH_3) ppm; nmr (CD_3CN)δ 7.63 (m,10,phenyl), 6.70 (s,1,H-6), 3.10 (s,3,CH_3) ppm.

Anal. Calcd for $C_{17}H_{14}BrClO_4S_2$: C, 44.22; H, 3.06; Br, 17.30; Cl, 7.68; S, 13.87. Found: C, 44.32; H, 3.14; Br, 17.58; Cl, 7.70; S, 13.64.

1-Trideuteriomethyl-2,5-diphenyl-1,4-dithiinium Tetrafluoroborate (XCV).-To a stirred solution of 1.62 g (6.04 mmols) of 2,5-diphenyl-1,4-dithiin and 4.35 g (30.0 mmols) of methyl iodide-d_3 of 99% isotopic purity in 20 ml of methylene chloride and 10 ml of nitromethane was added a solution of 2.14 g (5.94 mmols) of $AgBF_4 \cdot 4CH_3CN$ in 15 ml of nitromethane. The reaction mixture was allowed to stir for 5 hr and then the yellow solid was removed by filtration, washed with anhydrous ether and dried to give 1.10 g (78%) of silver iodide. The filtrate was diluted to 400 ml with anhydrous ether to give a buff precipitate. The material was collected by filtration and air dried to give 1.65 g (74%) of solid with mp 163-164° dec. Two recrystallizations from acetonitrile ether gave white crystals with mp 165-166° dec. The nmr spectrum of the material indicated that no loss in isotopic purity resulted during the preparation of the 1-trideuteriomethyl-2,5-diphenyldithiinium tetrafluoroborate; nmr (CF_3CO_2D) δ 8.15 (s,1, H-3), 7.65 (m,10,phenyl), 6.55 (s,1,H-3) ppm, and no absorption in the methyl region.

Anal. Calcd for $C_{17}H_{12}BD_3F_4S_2$: C, 54.70; H+D, 4.86; S, 17.18. Found: C, 54.67; H+D, 5.04; S, 17.27.

Reaction of 1-Methyl-2,5-diphenyl-1,4-dithiinium Tetrafluoroborate (LXXXI) with Dimethylsulfide.-To a solution of 2.26 g (6.10 mmols) of 1-methyl-2,5-diphenyl-1,4-dithiinium tetrafluoroborate in 15 ml of acetonitrile was added 2.00 g (35.2 mmols) of dimethylsulfide. After the solution was stirred overnight at room temperature, the solvent was evaporated and then ether was added to the yellow residue. The solid which did not dissolve in the ether was collected by filtration, washed with ether, and air dried to give 0.82 g (82%) of a buff solid with mp 200-208°. One recrystallization from acetonitrile-ether gave a white solid with mp of 205-208° and exhibited an nmr spectrum (CD_3CN), showing only a sharp methyl singlet at δ 2.90 ppm. (The lit.[60] mp of trimethylsulfonium tetrafluoroborate is 206-211°). The ether solution was then evaporated to give 1.30 g (79%) of a yellow solid with mp 110-113°. One recrystallization from absolute ethanol yielded a yellow solid with mp 112-114°. A mixed melting point with genuine 2,5-diphenyl-1,4-dithiin was undepressed.

An nmr experiment was then done using essentially the same molar ratios of reactants. The peaks associated with the starting materials began to disappear after 30 min and the peaks associated with the products began to appear.

Another nmr experiment was done using thioanisole as the attacking sulfide. The reaction showed noticeable progress after 12 hr. The only product peaks which appeared after 48 hr were those associated with 2,5-diphenyl-1,4-dithiin and the dimethylphenylsulfonium ion.

Reaction of 1-Methyl-2,5-diphenyl-1,4-dithiinium 2,4,6-Trinitrobenzenesulfonate (LXXIX) with Piperidine.-To a solution of 1.00 g (1.74 mmol) of 1-methyl-2,5-diphenyl-1,4-dithiinium 2,4,6-trinitrobenzenesulfonate in 15 ml of acetonitrile was added 0.74 g (8.70 mmols) of piperidine. The resulting solution was stirred at room temperature for 24 hr and then the solvent was evaporated to give a yellow solid. Ether was added to the solid and the portion of the solid which did not dissolve was collected by filtration, washed with ether, and air dried to give 0.55 g (81%) of a pale yellow material with decomposition point above 200°. The material was recrystallized from acetonitrile-ether to give a buff solid with mp 233-237° with gradual decomposition above 210°.

The filtrate was then evaporated to give 0.37 g (79%) of a yellow solid. One recrystallization from absolute ethanol resulted in a yellow solid with mp 111-114°. A mixed melting point with genuine 2,5-diphenyl-1,4-dithiin was undepressed.

The above mentioned buff solid was identical with N-methylpiperidinium 2,4,6-trinitrobenzenesulfonate prepared as follows:

N-Methylpiperidinium 2,4,6-Trinitrobenzenesulfonate.-To a stirred solution of 2.27 g (0.010 mol) of N-methylpiperidinium iodide in 10 ml of methylene chloride and 5 ml of nitromethane was added dropwise over a period of 5 min a solution of 5.23 g (0.010 mol) of $AgTNBS\cdot 3CH_3CN$ in 10 ml of nitromethane and 0.5 ml of acetonitrile. When the addition was complete, the resulting mixture was stirred for 1 hr, and then the silver iodide was removed by filtration. The filtrate was stirred rapidly and diluted with excess ether to give a white solid which was collected by filtration and air dried. The product amounted to 3.80 g (97%) with mp 235-238° dec.; nmr ($DMSO$-d_6) δ 8.72 (s,2,TNBS$^-$), 8.17 (broad low-lying band, 1,N-H), 3.08 (strong s plus m,7,CH_3 plus two αCH_2), 1.63 (broad s,6, two β and one γ CH_2) ppm.

Anal. Calcd for $C_{12}H_{16}N_4O_9S_2$: C, 36.73; H, 4.11; N, 4.28; S, 8.17. Found: C, 36.44; H, 4.03; N, 4.39; S, 8.31.

Methyl Phenacyl Sulfide (XCIII).-This compound was prepared by the method of Long.[61]

To a cooled solution of 4.00 g (0.100 mol) of sodium hydroxide in 80 ml of 50% ethanol was added slowly with good stirring 5.80 g (0.100 mol) of methanethiol. To the resulting solution was added in one portion 15.5 g (0.100 mol) of phenacyl chloride. The mixture was refluxed for 45 min, cooled, and then diluted with two volumes of water. The mixture was extracted twice with 20 ml portions of ether. The ether extracts were combined and dried over anhydrous magnesium sulfate. The solvent was evaporated to give an oil which was distilled to give 13.0 g (78%) of a very pale yellow liquid with bp 75-77° (0.01 mm) (lit.[61] bp 102-104° (2 mm)).

1-Butylthio-2-methylthio-1-phenylethylene (XCI).-A mixture of 13.0 g (0.0781 mol) of methyl phenacyl sulfide, 7.08 g (0.0781 mol) of butanethiol and 0.75 g of p-toluenesulfonic acid in 100 ml of benzene was refluxed for 6 hr. (The water formed during the course of the reaction was collected in a Dean Stark trap). At the end of 6 hr, no more water was evolved but only 1.0 ml of water was collected (72% of the theoretical amount). The solvent was evaporated to ½ of the total volume; the reaction mixture was poured into water, and was washed with a 5% aqueous sodium bicarbonate solution. After a final water washing of the organic layer, the layer was dried over anhydrous magnesium sulfate. The solvent was evaporated to give a yellow oil which was distilled at reduced pressure to give four fractions collected at 0.01 mm:

fraction 1:	75°	0.9 g	
fraction 2:	$75\text{-}77^{\circ}$	7.5 g	methyl phenacyl sulfide
fraction 3:	$95\text{-}100^{\circ}$	2.9 g	methyl phenacyl sulfide and 1-butylthio-2-methylthio-1-phenylethylene
fraction 4:	$120\text{-}125^{\circ}$	6.0 g	1-butylthio-2-methylthio-1-phenylethylene.

Fraction 4 was redistilled twice to give a pale yellow liquid with bp $110\text{-}111^{\circ}$ (0.005 mm); ir (neat) 3070,3050, 3010 weak (vinyl and aromatic C-H), 2950,2920,2870,2850, all strong (aliphatic C-H), and other strong bands at 1595, 1540,1484,1462,1440,1273,815,755, and 695 cm^{-1}; nmr (CCl_4) δ 7.40 (m,5,phenyl), 6.58 and 6.53 (two singlets, total 1, vinyl C-H), and the remaining 12 aliphatic protons distributed among the following: 2.60 (m), 2.30 (s), 1.97 (s), 1.40 (m), 0.90 (m) ppm. Among this last group the nmr bands were not well enough resolved to permit distinct integrations.

Anal. Calcd for $C_{13}H_{18}S_2$: C, 65.49; H, 7.61; S, 26.90. Found: C, 65.66; H, 7.83; S, 26.61.

Reaction of 1-Methyl-2,5-diphenyl-1,4-dithiinium Tetrafluoroborate (LXXXI) with n-Butyllithium. -To a well stirred mixture of 1.46 g (0.210 mol) of lithium metal cut into small pieces in 75 ml of ether (distilled from sodium hydride) cooled to -10° was added dropwise over a period of an hr 14.4 g (0.105 mol) of n-butyl bromide. The reaction mixture was cooled and stirred an additional hr and then the resulting solution was cooled to -55° at which time 7.79 g (0.0210 mol) of 1-methyl-2,5-diphenyl-1,4-dithiinium tetrafluoroborate was added. The cooling bath was removed and the mixture was allowed to warm to room temperature. A reaction began to occur at about -10° and a more rapid reaction set in when the temperature reached 0°. A total of 1 hr was required for the reaction to go to completion. The reaction mixture was poured and vigorously stirred into cold water. The layers were separated and the water layer was then extracted with ether and then the organic layers were combined and dried over anhydrous magnesium sulfate. The ether was removed by distillation through a 24 cm Vigreux column. The residual liquid was distilled at reduced pressure (8 mm) and at

25° to give 1.05 g of material which was predominately phenylacetylene. The remaining liquid was distilled at reduced pressure to give 2.18 g (43.6%) of a yellow liquid with bp 115-120° (0.05 mm). Redistillation of the first liquid gave 0.90 g (42%) of a colorless liquid with bp 142-144°. The infrared spectrum (neat) 3280 (ethynyl C-H) and 2110 ($C\equiv C$) cm^{-1}, of the liquid was identical with the spectrum of phenylacetylene (lit.[62] bp 142-144°). Redistillation of the second yellow liquid gave 1.8 g (36%) of a yellow oil with bp 118-120° (0.05 mm). The infrared and nmr spectra of the liquid were identical with the spectra of 1-butylthio-2-methylthio-1-phenylethylene.

The residual semisolid from the first distillations was scratched with absolute ethanol to give 2.5 g (44%) of a yellow solid with mp 124-126°. After one recrystallization from absolute ethanol, the yellow solid had a mp of 116-118° and had an infrared spectrum identical with the spectrum of 2,5-diphenyl-1,4-dithiin. A mixed melting point of the yellow solid and 2,5-diphenyl-1,4-dithiin was undepressed.

In another experiment using commercial n-butyllithium of unknown concentration in hexane the reaction was done essentially the same except that the filterable solids were removed from the reaction mixture before the work-up procedure. The solid material proved to be predominately 1-methyl-2,5-diphenyl-1,4-dithiinium perchlorate (LXXX) by mp 164-165°.

Reaction of 1-Methyl-2,5-diphenyl-1,4-dithiinium Tetrafluoroborate (LXXXI) with Sodium Hydride.-To a slurry of 0.41 g (10 mmols) of a 59.6% mineral oil dispersion of sodium hydride and 1.51 g (10 mmols) of 4-nitrobenzaldehyde in 30 ml of dry glyme (glyme was dried over and distilled from sodium hydride) cooled to -55° was added 3.70 g (10 mmols) of 1-methyl-2,5-diphenyl-1,4-dithiinium tetrafluoroborate. The resulting slurry was allowed to warm slowly. At -10° a noticeable reaction began and continued for about 45 min during which time the slurry turned yellow green and the temperature of the reaction reached room temperature. After the mixture was allowed to stir an additional 15 min, the reaction mixture was poured into water and then was extracted with benzene. The organic layer was dried over anhydrous magnesium sulfate and then the solvent was evaporated to give a yellow oil which was placed on a chromatography column and eluted with benzene. The first three fractions collected were shown to be identical by their infrared spectra. A total of 2.2 g of a pale yellow oil which solidified on standing was obtained. Four recrystallizations from absolute ethanol gave white crystals with mp 72-74°. The material was shown to be 1-phenylethynylthio-2-methylthio-1-phenylethylene by the nmr and infrared spectra. The 2.2 g of product represents 78% of the theoretical yield. The next two fractions collected amounted to 0.50 g. Nmr and infrared spectra indicated that this material was a mixture of 1-phenylethynylthio-2-methylthio-1-phenylethylene and 4-nitrobenzaldehyde. The last four fractions contained a total of 1.45 g (96%) of a pale yellow solid which was shown to be 4-nitrobenzaldehyde by the nmr and infrared spectra.

Since the 4-nitrobenzaldehyde played no apparent part in the reaction, the reaction was repeated as described above except that the 4-nitrobenzaldehyde was not one of the reactants. When the reaction was complete, a white solid was collected by filtration and then washed with ether. The filtrate, which now contained ether, yielded more white solid. The two batches were combined and dried to give 1.10 g (100%) of material with a decomposition range above 380°. The white solid was shown to be sodium tetrafluoroborate. The filtrate was evaporated to yield

2.80 g (99%) of a pale yellow oil which solidified on cooling. One recrystallization from absolute ethanol resulted in a white product with mp 71-74°. The infrared and nmr spectra were identical with the spectra of 1-phenylethynylthio-2-methylthio-1-phenylethylene. A mixed melting point with genuine material was undepressed.

Spectral data for 1-phenylethynylthio-2-methylthio-1-phenylethylene are as follows: ir (KBr) 3065,3045, 3000 (aromatic and vinyl C-H), 2940 sh, 2915,2845 (CH_3), 2160 ($C \equiv C$), and strong bands at 1590,1545,1479,1435,1318, 1249,906,811,750,and 685 cm^{-1}; nmr (CCl_4) δ 7.40 (m,5, phenyl), 7.17 (s,5,phenyl), 6.55 (s,1,vinyl H), and 2.40 (s,3,CH_3) ppm; mass spectrum m/e 282 (parent peak) and 267 (parent minus CH_3).

Anal. Calcd for $C_{17}H_{14}S_2$: C, 72.30; H, 5.00; S, 22.70. Found: C, 72.50; H, 5.28; S, 22.60.

Reaction of 1-Trideuteriomethyl-2,5-diphenyl-1,4-dithiinium Tetrafluoroborate (XCVI) with Sodium Hydride.-To a slurry of 0.137 g (3.24 mmols) of a 56.9% mineral oil dispersion of sodium hydride in 15 ml of dry glyme (glyme was dried over and distilled from sodium hydride) cooled to -75° was added 1.20 g (3.24 mmols) of 1-trideuteriomethyl-2,5-diphenyl-1,4-dithiinium tetrafluoroborate. The resulting slurry was allowed to warm slowly. At -10° a noticeable reaction began and continued for 45 min during which time the slurry turned pale yellow and the temperature of the reaction reached room temperature. After the mixture was allowed to stir an additional 15 min, a yellow solid was collected by filtration and then washed with ether. The filtrate which now contained ether yielded more yellow solid. The filtrate was evaporated to yield 0.84 g (92%) of a yellow solid. An nmr spectrum of the crude solid indicated that only 1-phenylethynylthio-2-trideuteriomethylthio-1-phenylethylene resulted from the reaction. Two recrystallizations from absolute ethanol gave a white solid with mp 69-71°. The product showed no depression of the melting point of the protio-analog. The retention of isotopic purtiy was shown spectrally by ir (KBr) 3065,3045, 3005 (aromatic and vinyl C-H), 2160 (C≡C), 2130 (C-D), and strong bands at 1590,1548,1480,1438,1254,1010,940,911, 820,750, and 690 cm^{-1}; nmr (CCl_4) δ 7.40 (m,5,phenyl), 7.17 (s,5,phenyl), and 6.55 (s,1,vinyl C-H) ppm without any methyl absorption; mass spectrum m/e 285 (parent peak and 267 (parent minus CD_3).

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