REACTIONS OF DIAZOKETONES WITH NEIGHBORING CARBON-TO-CARBON DOUBLE BONDS

by

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of the requirements for
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ABSTRACT

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Department of Chemistry   March, 1978.

It was hoped that the carbon-carbon double bond in an unsaturated diazoketone would act as a nucleophile in an intramolecular attack to give a ring closure. Experimental results indicate that the double bond did participate, but in such a manner so as to give only substituted products, rather than cyclic ones. We suggest a diazonium salt intermediate in the initial formation of these substituted products. Polymerization and oxonium ion formation after reaction with a Lewis acid and solvent account for the polymers formed and some of the substituted products.

This Thesis

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INTRODUCTION and THEORY

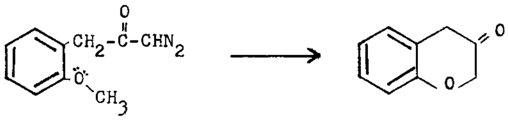
This thesis deals with the possibility of a π system, in this case a carbon-carbon double bond, acting as a nucleophile in an intramolecular attack of a diazoketone to give a ring closure. While not much work has been done in this area, Smith, Branca, and Toder[1] devised a synthesis of a cyclopentenone ring which used intramolecular π bond participation in forming the ring.

In their work, the best yields were reported in cases where a tertiary carbonium ion intermediate could be formed. We are interested in following up their work to see whether, in other systems, a double bond can participate in ring formation.

In all of our compounds, the most stable carbocation that can be formed is a secondary one, which may decrease the possibility of ring formation. Their system was β,γ to the carbonyl group, while three of our compounds have γ,δ systems which may alter the possibility of ring formation.

While non-bonding pairs of electrons can be used as nucleophiles to effect cyclization[2] as seen in (1),

(1)



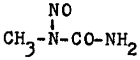
we are interested in obtaining cyclic structures from double bond participation. In order to accomplish this though, there must be, at the most, weak nucleophilic species present in the reaction mixture. A strong nucleophile would compete with the double bond. Since the π system is a weak nucleophile, the strong nucleophile would dominate the attack and very little ring formation would occur.

The synthesis of these compounds begins with the conversion of a suitable acid to its acid chloride. In our case, a suitable acid was one in which a carbon-carbon double bond was β,γ or γ,δ to the carbonyl group.

Several methods have been used in the past to successfully complete the transformation of acid to acid chloride. The most common are reacting the acid with thionyl chloride ($SOCl_2$), oxalyl chloride ($(COCl)_2$), or phosphorus pentachloride (PCl_5). Thionyl chloride was employed because it was found that the oxalyl chloride masks the acid and acid chloride carbonyl bands in the infra-red. The C=O stretch for an acid chloride is typcally at 1800 cm^{-1} while that for the acid is 1720 cm^{-1}. Infra-red spectroscopy was used to monitor the formation of the acid chloride.

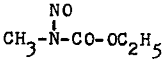
In most instances good yields are obtained via this method,[3,4,5,6] although in a few reported cases tars resulted and the yield was low.[7]

Following this, the next step was the production of diazomethane (CH_2N_2). The most common method for the formation of this product is by the base catalyzed decomposition of an N-methyl-N-nitroso compound. Three of the most common intermediates are nitroso-methylurea (I), nitrosomethylurethan (II), and bis(N-methyl-N-nitroso) terephthalamide (III).



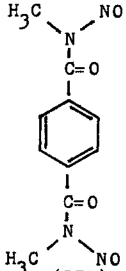
$CH_3-\overset{NO}{\overset{|}{N}}-CO-NH_2$

(I)



$CH_3-\overset{NO}{\overset{|}{N}}-CO-OC_2H_5$

(II)

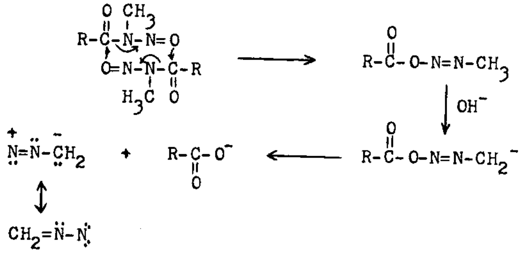


(III)

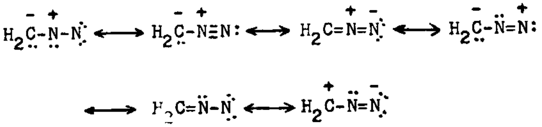
The latter was the compound employed by us in the formation of diazomethane. Compound (III) also goes by the trade name of EXR-101.

As can be seen, the integral part of each of these compounds is the $CH_3-\underset{|}{N}-NO$ group. Below is the mechanism for the dissociation of EXR-101.

(2)



Diazomethane has a variety of resonance structures associated with it.



$$H_2\overset{-}{C}-\overset{+}{N}-\ddot{N}: \longleftrightarrow H_2\overset{-}{C}-\overset{+}{N}\equiv N: \longleftrightarrow H_2C=\overset{+}{N}=\overset{-}{N}: \longleftrightarrow H_2\overset{-}{C}-\ddot{N}=\overset{+}{N}:$$

$$\longleftrightarrow H_2C=\ddot{N}-\dot{N}: \longleftrightarrow H_2\overset{+}{C}-\ddot{N}=\overset{-}{N}:$$

Diazoketones, with the general formula $R-\overset{O}{\overset{\|}{C}}-CHN_2$, were first reported at the beginning of this century by Wolff. Subsequent to that, Arndt and Eistert found that carboxylic acid chlorides or bromides could be converted into diazoketones almost without exception and in good yields when they were added to a cold solution of an excess of diazomethane.[8]

Research into the mechanism for the formation of diazoketones from acid halides was conducted by Arndt, Bradley, and Schwarzenbach.[9] They determined that first the diazomethane is acylated by the acid chloride (3).

(3) 

$$R-\overset{O}{\overset{\|}{C}}-Cl + CH_2N_2 \longrightarrow R-\overset{O}{\overset{\|}{C}}-CHN_2 + HCl$$

(4) 

$$R-\overset{O}{\overset{\|}{C}}-CHN_2 + HCl \longrightarrow R-\overset{O}{\overset{\|}{C}}-CH_2Cl + N_2$$

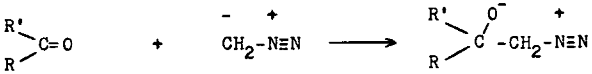
(5) $$HCl + CH_2N_2 \longrightarrow CH_3Cl + N_2$$

An excess (at least two equivalents) of diazomethane intercepts the hydrogen chloride and converts it into methyl chloride (5). If an excess were not used then the newly formed diazoketone would react with the hydrogen chloride to give the chloromethylketone (4).

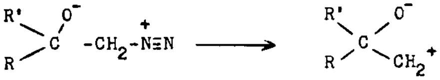
Eistert found that if the acid chloride isn't too reactive, then the diazoketone synthesis could be carried out in an alcoholic medium rather than the typical etheral medium.[10] As a side note, Newman and Beal[11] found that if an equivalent of triethyl amine was present to react with the hydrogen chloride, then only one equivalent of diazomethane was required. This method produced aromatic diazoketones in high yield.

The reactivity of diazomethane is not limited to acid chlorides, however. They attack carbonylgroups as well. It was Curtis who first observed that aldehydes reacted with diazomethane with nitrogen being evolved,[8] but the schools of Arndt, Meerweir, and Moettig systematically studied the field. Through the mechanism they proposed, three products were possible.

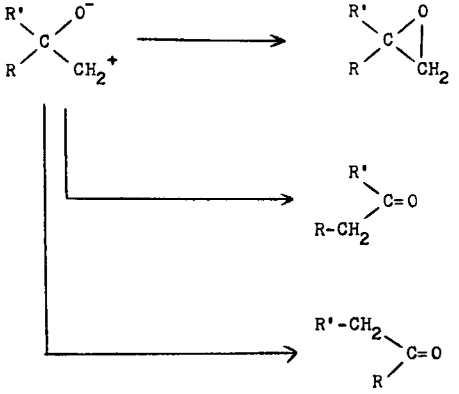
(6)



(7)



(IV)



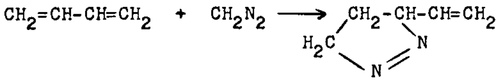
(V)

(VI)

(VII)

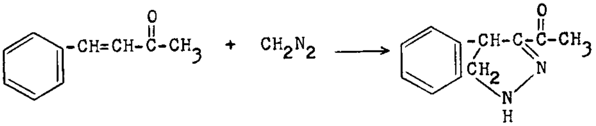
In their scheme, the diazomethane acts as a nucleophile with the negative carbon heading towards the δ^+ carbon on the carbonyl group (6). Then nitrogen is evolved (7) and the resulting intermediate (IV) can form the epoxide (V) or either of the next higher homologues of the ketone (VI, VII).

Double bonds also react with diazomethane. Generally though, these bonds are strained or activated (conjugated) double bonds. This reaction occurs with butadiene which yields vinyl pyrazoline (VIII).[12]



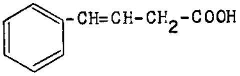
(VIII)

At times even the double bond is more reactive than a carbonyl group as seen in the reaction of benzylideneacetone (IX).[13]

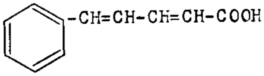


(IX)

Apparently the benzylidene carbon atom is a more favorable electrophilic center than the carbonyl carbon and therefore Michael type reactions characteristic of unsaturated ketones are observed. It should be noted that two of our starting materials, styrylacetic acid (X), and 5-phenyl-2,4-pentadienoic acid (XI) have conjugated systems.



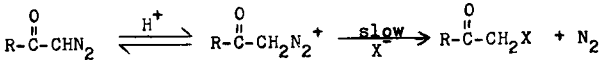
(X)



(XI)

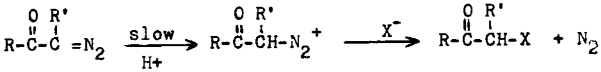
Once the diazoketone is made, all that remains is the reaction with the Lewis acid, hopefully leading to the cyclic product.

The reactions of diazoketones with Lewis acids proceed by two accepted mechanisms.[14] Diazomethylketones usually undergo fast reversible protonation (9) followed by substitution involving the conjugate base as a nucleophile in the rate determining step, i.e. an A2 mechanism.

(9) 

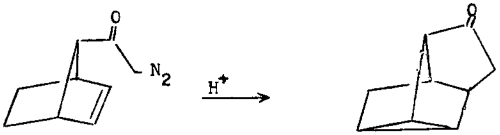
$$\mathrm{R-\overset{O}{\overset{\|}{C}}-CHN_2 \xrightleftharpoons{H^+} R-\overset{O}{\overset{\|}{C}}-CH_2N_2^+ \xrightarrow[X^-]{slow} R-\overset{O}{\overset{\|}{C}}-CH_2X + N_2}$$

However, in a more highly substituted diazoketone, protonation is the rate determining step. (10)

(10) 

$$\mathrm{R-\overset{O}{\overset{\|}{C}}-\overset{R'}{\overset{|}{C}}=N_2 \xrightarrow[H+]{slow} R-\overset{O}{\overset{\|}{C}}-\overset{R'}{\overset{|}{C}}H-N_2^+ \xrightarrow{X^-} R-\overset{O}{\overset{\|}{C}}-\overset{R'}{\overset{|}{C}}H-X + N_2}$$

Equation (9) is characterized by a solvent isotope effect of $^{k}H_2O/k_{D_2O} = 0.3-0.5$ and (10) by $^{k}H_2O/k_{D_2O} > 1$. But in (11), Dahn[15] obtained a $^{k}H_2O/k_{D_2O} = 1.74$. This

(11) 

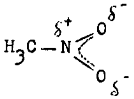
(XII)

case is particularly important for us because the double bond effectively competed in the reaction producing (XII).

As previously mentioned, we didn't want any strong nucleophilic species present in the reaction mixture due to the weak nucleophilicity of the double bond. Therefore, acids with weak conjugate bases and nonnucleophilic solvents had to be found. Some previous methoxy neighboring group studies[2] used diethyl ether as the solvent. However, one of their products was the ethoxy ketone, indicating that the ether, with the non-bonding electrons on the oxygen, acted as a nucleophile. In that study, conjugate bases of the acids used as catalysts, acetic and sulfuric, were also reacting as nucleophiles to give the substituted ketones, thus competing with the methoxy group.

Two solvents were found possessing both high polarity and low nucleophilicity, namely anhydrous nitromethane and trifluoroacetic acid. Boron trifluoride etherate, fluoroboric acid, 2-bromopyridinium perchlorate - which serves as a safe equivalent of anhydrous perchloric acid - and trifluoroacetic acid have been used as suitable acid catalysts.[14] The system most often chosen for this type of reaction was $BF_3 \cdot Et_2O$ in CH_3NO_2 which we also used.

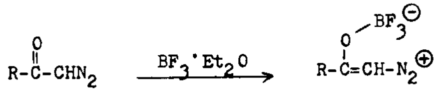
However, even when boron trifluoride etherate was used as the Lewis acid catalyst, some fluorinated product was formed[2] indicating that the fluorine in BF_3 can act as a nucleophile and might compete to a small extent with the olefinic double bond system. In addition, nitromethane nay be slightly nucleophilic too. In (XIII) you can see that the oxygens carry a partial



(XIII)

negative charge.

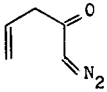
When boron trifluoride is used with diazoketones it is generally thought that the BF_3 complexes with the carbonyl oxygen in the diazoketone giving (XIV)[1,2]

(12)


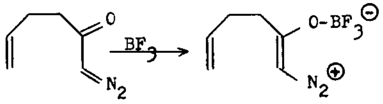
$$R\text{-}\overset{O}{\overset{\|}{C}}\text{-}CHN_2 \xrightarrow{BF_3 \cdot Et_2O} R\text{-}\overset{O\text{-}BF_3^{\ominus}}{\overset{|}{C}}\text{=}CH\text{-}N_2^{\oplus}$$

(XIV)

In our compounds, the R group contains a double bond in either β, γ (XV) or γ, δ (XVI) positions.

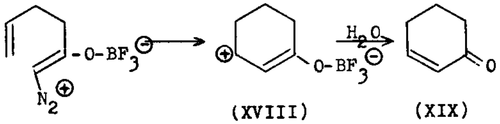


(XV)



(XVI) (XVII)

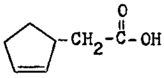
Attack by the Lewis acid on (XVI) gives the complex (XVII). The nucleophilic attack by the γ,δ double bond would produce the intermediate (XVIII).



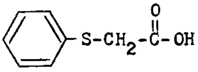
(XVIII) (XIX)

Hydrolysis of (XVIII) would produce (XIX). A bicarbonate wash is employed to purify (XIX).

The four acids under consideration by us are 2-cyclopentene-1-acetic acid (XX), thiophenoxyacetic acid (XXI), styrylacetic acid (X), and 5-phenyl-2,4-pentadienoic acid (XI)

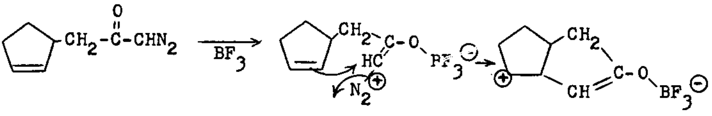


(XX)



(XXI)

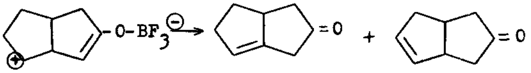
Initially we will consider the possible olefinic participation in the cyclopentene case. Attack of boron trifluoride etherate on the diazoketone (XXII) would give the intermediate (XXIII) which would be followed



(XXII) (XXIII) (XXIV)

by intramolecular attack on the diazo carbon with the evolution of nitrogen gas and ring closure to yield (XXIV), a secondary carbocationic intermediate. From here the cation could rearrange (13) to give 2(1H)

(13)

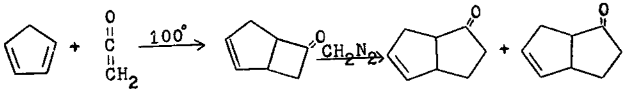


(XXV) (XXVI)

pentalenone 3,5,6,6a tetrahydro (XXV) and/or 2(1H) pentalenone 3,3a,6,6a tetrahydro (XXVI).

The bicyclic ketone (XXVI) has been previously prepared[16,17,18] though not in this fashion. Baldwin and others[16] produced it as shown in (14) below. They used

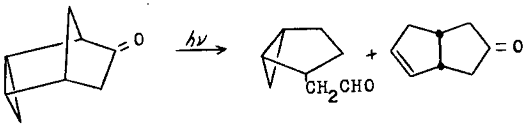
(14)



diazomethane creating the next higher homologue as shown in (8).

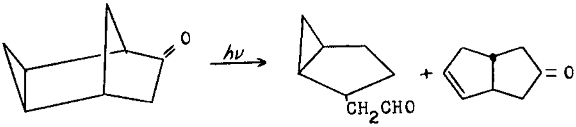
In addition, another group[18] synthesized both the cis and trans isomers of this pentalenone via the irradiation of endo and exo-tricyclo $3,2,1,0^{2,4}$ octan-6-one (XXVII) and (XXVIII).

(15)



(XXVII)

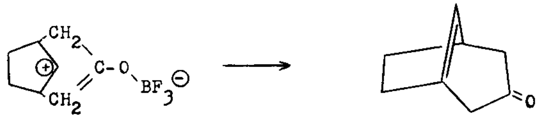
(16)



(XXVIII)

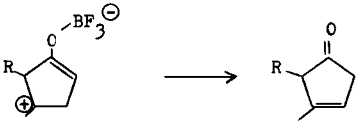
The yields were 29 % for the trans and 17 % for the cis.

It can be noticed from (XXIV) that the cation probably would be formed at the 4 position rather than the 3a position due to strain considerations. If this occurred the intermediate would be (XXIX) leading to a double bond at a bridgehead (XXX) which is quite strained.



(XXIX) (XXX)

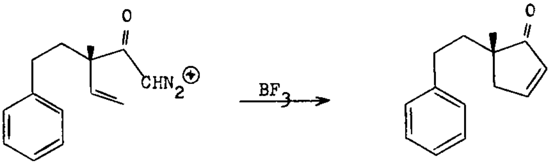
In Smith, Branca, and Toder's work,[1] they formed a tertiary cation (XXXI) which on treating with aqueous acid yielded 24-43% of the cyclopentenone.



(XXXI)

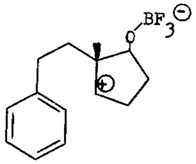
But when they attempted their method on a species that would proceed via a secondary carbocation, the yield was only 13% suggesting that a major driving force in the cyclization of the unsaturated diazoketone was the formation of a stable intermediate.

Smith and Dieter[19] also obtained some cyclic product via a secondary carbocation when (XXXII) , a β,γ unsaturated diazoketone was treated with $BF_3 \cdot Et_2O$



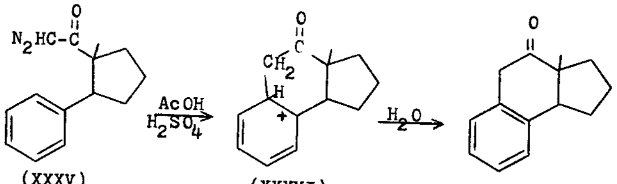
(XXXII) (XXXIII)

and nitromethane to yield (XXXIII). The intermediate was (XXXIV).



(XXXIV)

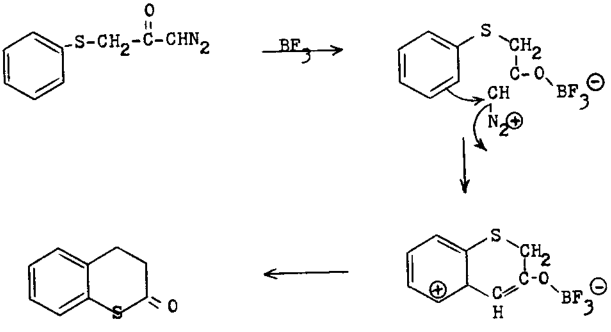
Newman and others[20], in working with a β-phenyldiazoketone (XXXV) succeeded in obtaining ring closure (XXXVII) with one of the double bonds in the benzene ring acting as the nucleophile.



(XXXV) (XXXVI) (XXXVII)

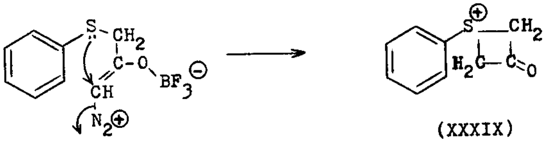
A tertiary carbocation formed (XXXVI), which, on hydolysis, yielded the tricyclic compound and restored the benzene ring.

From the diazoketone of thiophenoxyacetic acid, and in light of Newman's work, there is very little doubt that the major product should be the one which restores the aromaticity of the benzene ring. This product is 4H-1-benzothiopyran-3-one-2,4-dihydro (XXXVIII).



(XXXVIII)

Another possiblity is attack by sulfur's lone pair of electrons on the diazo group. This would produce an

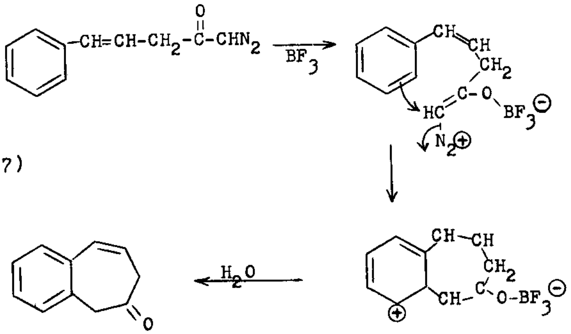


(XXXIX)

analog to aγpropiolactone and would result in a charged species which may be present in the form of a salt. However, the ring strain would be considerable. (XXXIX)

In the styrylacetic acid diazoketone there were two possibilities for π participation. One from the aromatic ring and the other from the β, γ double bond. In the former case (17), attack by the aromatic system would yield a seven membered ring (XL), much less favorable

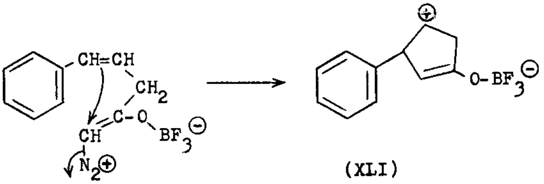
(17)



(XL)

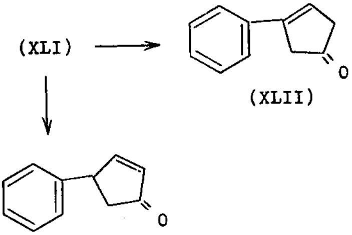
than the five-membered ring obtained if the β, γ double bond attacked (18). In this case, there are two possible

(18)



(XLI)

products of hydrolysis. One is that the double bond is formed in conjugation with the aromatic benzene ring to give 4-phenyl-3-cyclopentene-1-one (XLII). The other is that the



(XLII)

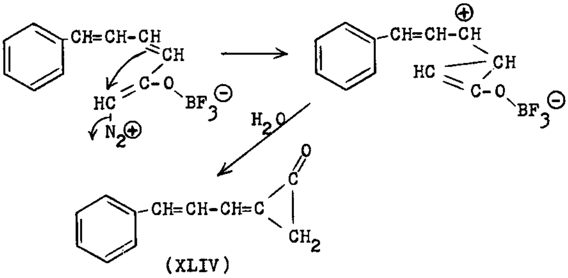
(XLIII)

double bond is conjugated with the carbonyl group to give 4-phenyl-2-cyclopentene-1-one (XLIII). Which product predominates depends on the relative stabilities associated with conjugation with an aromatic system and a carbon-oxygen double bond.

The last of the compounds under consideration was 5-phenyl-2,4-pentadienoic acid. In this case there were α,β and γ,δ double bonds, as well as a delocalized system in the benzene ring to serve as nucleophiles.

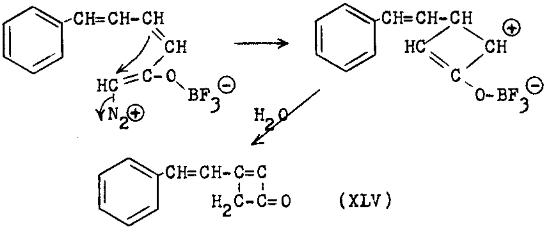
If the α,β double bond were attacking (19 and 20), then a three (XLIV),

(19)



or four membered ring structure (XLV) would result.

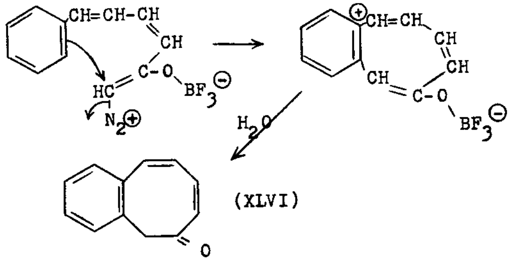
(20)



The α,β double bond is not considered too likely to attack due, in part, to a large strain induced in the rings, despite the fact that the entire system is conjugated.

The benzene ring as a source of nucleophilic attack (21) also seems unlikely because of the size of the ring that would be produced - eight-membered (XLVI)

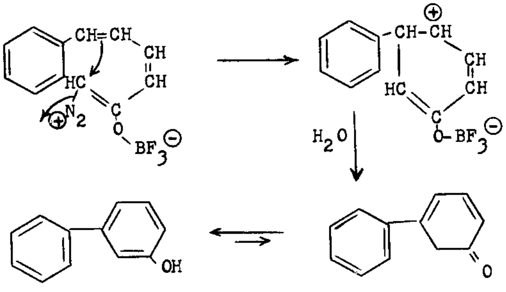
(21)



(XLVI)

It seems most logical that the γ,δ double bond would be the nucleophile. In this case, either a five or six membered ring can be produced.

(22)

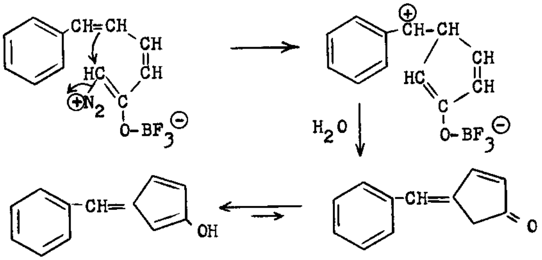


(XLVIII) (XLVII)

In the latter case, the hexadienone (XLVII) would be produced. However, due to a tendency for a system to acquire the greatest possible stability, the keto form would rearrange to give the more stable enol form (XLVIII), m-phenylphenol. This gains stability in the formation of a benzylic aromatic ring.

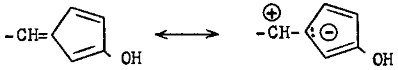
If the five membered ring were formed (23), then

(23)



(L) (IL)

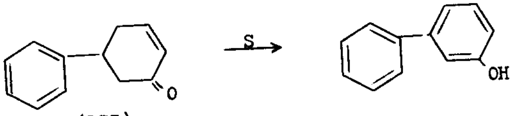
4-benzyladine cyclopentene-2-one (IL) would be produced. This may enolize to 4-benzyladine cyclopentadiene-1-ol (L). The enol form would be preferred since it is an aromatic system as seen in (LI).



(LI)

The six-membered m-phenylphenol has been synthesized in various ways. Two of the most common are via the Yarbord[21]- Hawthorne[22] method or that of Ames and Davey[23].

In the former case, synthsis was effected through a Grignard reagent then treatment with hydrogen peroxide. In the latter, the unsaturated ketone (LII) was dehydrogenated with sulfur.



(LII)

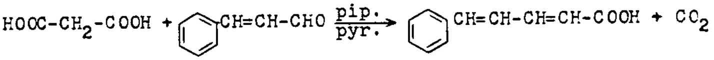
Some of the common uses of this compound are in the retardation of the fogging of silver halide emulsions[24,25] used in photography or in fabric dying.[26] The phenol apparently helps to stabilize the dye-bath and prevents spotting and clumping of the dye.

EXPERIMENTAL

I. Synthesis of 5-phenyl-2,4-pentadienoic acid

To 208 g.(2.0 moles) of malonic acid was added 400 ml. pyridine in a three neck, five liter round bottom flask, and mixed until dissolved. The solution was heated to 50° and 132 g. (1.0 mole) of cinnamaldehyde was added. Then 15 ml. of piperdine was introduced. The solution turned yellow-orange with the vigorous evolution of a gas (24)

(24)



The temperature was raised to 80-85° over 40 minutes with a run at this temperature for an additional 45 minutes. The solution was then refluxed for three hours at 115° . It was then cooled to 95° and added to four liters of cold water where the solution turned cloudy and yellow. Upon addition of 500 ml. of concentrated hydrochloric acid, a brown precipitate formed. The mixture was suction filtered and the crystals were washed four times with 150 ml. portions of cold water. The crystals were then added to a solution of 80 g. sodium hydroxide and three liters water. The resulting solution was filtered with slight suction. The filtrate was treated with 1200 ml. water and 600 ml. of 50% HCl. A yellow precipitate formed and was washed three times with 125 ml. portions of cold water. The yield was 104.9 g. of crude product; m.p. 136-40° . The crystals were dissolved in 1450 ml. of methyl ethyl ketone and filtered on a heated funnel. Most of the solvent was evaporated on a steam bath then the solution was placed in a refrigerator for twelve hours. Crystals formed and were suction filtered and dried. Yield: 32.6 g. ; m.p. 159-162.5° ,lit. 165-6°.[27]

$\delta(CDCl_3)$ 5.98(d, 1, α hydrogen), 7.14(pseudo-d, 2, β and γ hydrogens), 7.59(distorted-s, 6, δ and aromatic hydrogens), 9.1(broad, 1, hydroxyl hydrogen).

ν $CHCl_3$ 3000(broad,-COOH), 3000(aromatic H), 1685(-C=C-COOH, dimer), 1620(Ar-C=C-), 1415(-RCH=CHR-, cis), 1260(-COOH), 920(-COOH, dimer).

II. Synthesis of 5-phenyl-2,4-pentadienoic acid chloride

To 0.9 g. (0.005 mole) 5-phenyl-2,4-pentadienoic acid was added 1.75 g. (0.014 mole) thionyl chloride in a 50 ml. round bottom flask, and allowed to sit at room temperature for two weeks. The flask was fitted with a calcium chloride drying tube.

$\delta(CDCl_3)$ 6.08(d, 1, α hydrogen), 6.70-7.11(pseudo-d, 2, β and γ hydrogens), 7.38(distorted-s, 6, δ and aromatic hydrogens).

$\nu\,CHCl_3$ 3030(-CH=CH-), 2950(-CH=CH-), 1745(-C=C-COCl), 1620(Ar-C=C-), 1585(-C=C-, conjugated), 995(-RCH=CHR-, trans).

III. Synthesis of Styrylacetyl chloride

Batch 1- To 0.7 g.(0.004 mole) styrylacetic acid was added 2.3 g.(0.019 mole) thionyl chloride in a 100 ml. round bottom flask fitted with a calcium chloride drying tube. There was immediate evolution of a gas. This was allowed to sit at room temperature for 20 hours. The excess thionyl chloride was evaporated off and the orange-yellow crystals formed were dissolved in three ml. of warm ligroin(66-77°). The solution was filtered ans cooled in an ice bath. The crystals were suction filtered and dried; m.p. 34-7°, lit. 42°.[6] These were recrystalized two times from anhydrous diethyl ether and dried. Contamination with water reconverted the acid chloride back into the acid; m.p. 73-7°.

Batch 2- To 12.98 g.(0.080 mole) acid was added

13.8 g.(0.116 mole) thionyl chloride in a 100 ml. round bottom flask with a calcium chloride drying tube. The reaction was allowed to proceed for 96 hours, then the crystals were recrystalized two times from anhydrous ether; m.p. 44-5°.

Batch 3- To 9.8 g.(0.057 mole) of acid was added 12.8 g.(0.108 mole) thionyl chloride. Workup was the same as batch two; m.p. 45-6°.

δ(CDCl$_3$) 3.75(d, 2, -CH$_2$-), 5.94-6.87(d over sextet, 2, olefinic hydrogens), 7.41(s, 5, aromatic hydrogens).

ν_{CHCl_3} 3030(aromatic H), 1795(-COCl), 1450(-CH$_2$-C=C-), 960(-RCH=CHR-, trans).

IV. Synthesis of Thiophenoxyacetyl chloride

Batch 1- To 16.82 g.(0.100 mole) thiophenoxyacetic acid was added 23.8 g.(0.200 mole) thionyl chloride in a 100 ml.round bottom flask. The mixture was refluxed for two hours at 30 volts. The solution was distilled with the acid chloride coming over at 118° at 1 mm.; lit.: $b_{0.12}$ 72-4° [28], b_3 115-6° [29], b_6 117-9° [5], b_{12} 120-3° [30].

Batch 2- To 84.11 g.(0.50 mole) acid was added

168.2 g.(1.41 moles) thionyl chloride and refluxed together at 35 volts for three hours. Distillation at 6 mm. gave two fractions. The first coming over at 122-30° (5.5 ml.) and the second at 134-6° (10.5 ml.). Fraction one was about 40 percent acid chloride as determined from the IR, and two was almost pure acid. The remainder of the solution turned into a thick black tar that would not distill.

Batch 3- Added to 4.24 g.(0.026 mole) acid in a 100 ml. round bottom flask fitted with a calcium chloride drying tube was 4.79 g.(0.040 mole) thionyl chloride. The solution was left to react at room temperature for 48 hours, then the flask was flushed out with nitrogen and left in the refrigerator for a month.

δ(CDCl$_3$) 3.88(s, 2, methylene hydrogens), 7.22 (s, 5, aromatic hydrogens).

ν CHCl$_3$ 3030(aromatic H), 2940(-CH$_2$-), 2820 (-CH$_2$-), 1800(-COCl), 1440(-S-CH$_2$-).

Refractive index - 1.5946^{18}
lit.: 1.5826^{20} [30], 1.5806^{25} [5]

V. Synthesis of 2-cyclopentene-1-acetyl chloride

Batch 1- To 10 g.(0.079 mole) 2-cyclopentene-1-

acetic acid was added 11.9 g.(0.100 mole) thionyl chloride and refluxed for three hours. Upon addition of thionyl chloride to the acid, the solution turned from clear white to yellow, and then to dark red-black at the end of refluxing.

Batch 2- To 13.5 g.(0.107 mole) acid was added 25.4 g.(0.214 mole) thionyl chloride and refluxed together for one hour and then combined with batch one. The thionyl chloride was distilled off with a water aspirator. The acid chloride was then distilled under nitrogen at 5-7 mm., b 42-57°. Yield 15.11 g.(56%). There was also substantial tar formation in the flask on heating.

Batch 3- To 63.08 g.(0.500 mole) acid was added 168.2 g.(1.41 moles) thionyl chloride which were then refluxed together for three hours. The acid chloride distilled at 48° at 1mm., under nitrogen to yield 46.4 g. (64%).

Batch 4- To 49.34 g.(0.39 mole) acid was added 72.73 g.(0.61 mole) thionyl chloride in a 250 ml. round bottom flask fitted with a calcium chloride drying tube. The mixture was left at room temperature for 36 hours. The acid chloride was distilled under nitrogen at 37-8° at 1mm. to give 43.6g. (77%).

Batch 5- To 22.1 g.(0.18 mole) acid was added 39.0 g.(0.32 mole) thionyl chloride and set at room temperature for 72 hours. The acid chloride distilled under nitrogen at 1mm., b 39-40° . Yield 21.1 g.(81%).

Batch 6- To 66.85 g.(0.53 mole) acid was added 118.9 g.(1.00 mole) thionyl chloride which were refluxed together for five and one-half hours and then distilled under nitrogen. The acid clhoride was collected at 68° at 13 mm. The yield was 43.6 g. (57%). Again there was substantial tar formation.

Batch 7- To 100 g.(0.80 mole) of acid was added 154.7 g.(1.30 moles) thionyl chloride in a 500 ml. round bottom flask with a calcium chloride drying tube. The acid chloride was collected at 66-8° at 26-7 mm. The yield was 53.4 g.(46%). The low yield can be accounted for by a rupture in the nitrogen hose. On this run a spinning band column was used for distillation rather than the small distilling apparatus.

The pressures stated in the above batches may not be accurate due to a fluctuating manometer.

The literature boiling points are: b_{13} 65-75°[31], b_{28} 87°[3], b_{145} 122°[32].

$\delta(CDCl_3)$ 1.13-2.24(m, 2, e and f hydrogens), 2.24-2.63(m, 2, c and d hydrogens), 2.70-3.44(m, 3, g and h hydrogens), 5.76(quartet, 2, olefinic hydrogens).

$\nu\,CHCl_3$ 3020(-CH=CH-, cis), 2940($-CH_2-$), 2850 ($-CH_2-$), 1795(-COCl), 1340($-CH_2-CO-$).

VI. Preparation of Diazomethane

Batch 1- The general procedure followed for the preparation of diazomethane was the same as suggested in the literature[33] except that ground glass joints were used.

Into a five liter round bottom flask were added 1800 ml. diethyl ether (practical grade), 270 ml. 2-(2-ethoxyethoxy)ethanol and 360 ml. 30% sodium hydroxide which were cooled to -2° in an ice-salt bath. Then 108 g. of EXR-101 (bis(N-methyl-N-nitroso)terephthalimide) were added in one protion as the flask was immediately transfered to a heating mantle and distillation begun. Almost immediately the solution turned yellow and gas was evolved. The five liter receiving flask, cooled by an ice bath and fitted with a calcium chloride drying tube, contained enough anhydrous ether to cover the tip of the dropper leading from the condenser. Distillation was continued until the distillate was clear. The diazomethane in ether solution distilled at 34-7° .

Batch 2- To a two liter round bottom flask was added 450 ml. ether, 90 ml. 30% NaOH, and 67.5 ml. of 2-(2-ethoxyethoxy)ethanol and cooled to -2° . Then 27 g. of EXR-101 were added and distillation begun with ethereal diazomethane coming over at 35-7° .

Batch 3- To a five liter flask was added 1350 ml. ether, 270 ml. 30% NaOH, and 202.5 ml. 2-(2-ethoxyethoxy) ethanol and cooled to -1° . Then 81 g. of EXR-101 were added and distillation begun. The remainder of the procedure was the same as above.

Batch 4- In a two liter flask was placed 1002 ml. ether, 200 ml. 30% NaOH, and 150 ml. 2-(2-ethoxyethoxy) ethanol and cooled to -1.5° . Then 61.2 g. EXR-101 were added and the reaction was carried out in a similar manner.

Batch 5- In a five liter round bottom flask were placed 2664 ml. ether, 536 ml. 30% NaOH, and 400 ml. 2-(2-ethoxyethoxy)ethanol which were cooled to -2° . After this, 106 g. EXR-101 were added and the reaction continued as above.

Batch 6- To a two liter flask was added 990 ml. ether, 144 ml. 2-(2-ethoxyethoxy)ethanol, and 192 ml. 30% NaOH and cooled to -0.5° . Then 57.6 g. EXR-101 were added and the reaction continued as before.

Batch 7- In a five liter flask was placed 2664 ml. ether, 400 ml. 2-(2-ethoxyethoxy)ethanol, and 535 ml. 30% NaOH which were cooled to -1.5° . Then 160 g. of EXR-101 were added and the reaction carried out as above. The yield of diazomethane for this batch was determined by titration with benzoic acid and gave 78%.

VII. Synthesis of 2-cyclopentene-1-acetyl methyldiazoketone

Batch 1 - To the diazomethane produced in batch one was added, dropwise, 35.8 g.(0.249 mole) of 2-cyclopentene-1-acetyl chloride. The reaction was allowed to proceed for 21 hours, initially at ice bath temperature, then rising to room temperature. The ether was then evepnorated off by a water aspirator. A water layer was noticed as well as a white fluffy precipitate in the solution. The diazoketone was dried with anhydrous sodium sulfate, filtered, and the remaining ether evaporated. The yield was 30.5 g. (81%).

Batch 2 - To batch two of diazomethane was added 9.35 g.(0.064 mole) acid chloride. The reaction proceeded for 23 and three-quarters hours. The ether was evaporated and the diazoketone yield, after drying, was 6.65 g.(72%).

Batch 3 - Added to batch three of the ethereal diazomethane was 27.7 g.(0.19 mole) acid chloride, which was allowed to react for 16 hours. The remaining procedure is the same as above. Yield was 32.7 g. which was greater than 100%, so 100% conversion was assumed.

Batch 4 - To the diazomethane of batch four was added 20.3 g.(0.141 mole) acid chloride and the reaction proceeded for 22½ hours. The remainder of the procedure is as above, in the first batch. The yield was 15.24 g.(87%).

Batch 5 - To batch five of diazomethane was added 53.45 g.(0.37 mole) of acid chloride. The reaction proceeded as above for 18 hours. The yield was 107.9 g., which was 45% diazoketone from the NMR. The product yield was 48.6 g.(87%).

Batch 6 - To diazomethane batch seven was added 26.7 g.(0.185 mole) acid chloride. The reaction proceeded for twelve hours and the NMR showed the 48.4 g. yield was 67% ether. The yield of diazoketone was 15.9 g.(57%).

In all the diazoketone synthesis, a white precipitate was formed which was filtered out.

VIII. Reaction of 2-cyclopentene-1-acetyl methyldiazoketone with boron trifluoride etherate and nitromethane

Trial 1 - To 30.5 g.(0.203 mole) of diazoketone was added 30.5 g.(0.50 mole) nitromethane. Then 1.1 equivalents (31.7 g.) of boron trifluoride etherate were added dropwise. There was vigorous evolution of a gas and the reaction mixture turned dark brown. The flask was allowed to sit for 15 minutes,until the evolution of gas ceased, in an ice bath. Then 28 ml. of 10% HCl were added to the solution, which was then refluxed for two hours. The thick black solution was distilled and four fractions were obtained which were found to be ether, water, and nitromethane. Most of the material solidified into a solid mass on heating.

Trial 2 - To 6.65 g. (0.046 mole) diazoketone and 7.14 g. (0.12 mole) nitromethane was added 1.1 equivalents of boron trifluoride etherate (7.19 g.) which was followed by the rapid evolution of a gas. The mixture was allowed to react for 15 minutes, then refluxed with 16.3 g. 10% HCl for two hours. On cooling, the solution was washed twice with 25 and 20 ml. portions of 10% sodium bicarbonate. On the first washing, there was release of a gas. The solution was distilled under nitrogen with the solvents coming off at pressures 87-140 mm. After 42 minutes, four ml. of benzene were added to azeotrope out any remaining water. The distillation was continued at 33 mm. with pot temperatures less than 25° . Only tar resulted which was run through the vapor phase osmometer. Molecular weights obtained for the tar were 396, 380,338, and 333. The average is 362 g./mole.

Trial 3 - To 15.24 g. (0.123 mole) of diazoketone was added 14.76 g. (0.246 mole) nitromethane, then 19.21 g. (0.135 mole) boron trifluoride etherate, dropwise. The mixture reacted for 15 minutes then was washed once with 50 ml. water, and twice with 50 ml. portions of 10% sodium bicarbonate. The pH of the resulting solution was seven to eight. The mixture was distilled at 1 mm., and three fractions were obtained. Fraction 1: b_1 44-50°, 0.8 ml., 0.639 g.; fraction 2: b_1 50-58°, 0.809 g.; fraction 3: b_1 58-70°, 0.109 g. The gas chromatograph of each fraction showed six components present; 2a, 2b, 3, 4, 5, 6. The relative yields were 2a,b - 28.0%, 3 - 33.1%, 4 - 35.2%, 5 - 2.5%, 6 - 1.2%. A comparison of the retention times with the boron trifluoride and ether runs showed that these components are the same as found in those runs.

IX. Reaction of 2-cyclopentene-1-acetyl methyldiazoketone with boron trifluoride etherate and ether

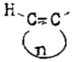
Trial 1 - To 29.6 g.(0.40 mole) of anhydrous diethyl ether was added 27.7 g.(0.19 mole) of diazoketone. Then 1.1 equivalents (31.2 g.) of boron trifluoride etherate were added dropwise. After the initial drop, there was a lag of 15 seconds then a vigorous evolution of gas. The mixture was allowed to react at room temperature for 15 minutes after the end of the gas evolution. The solution was then transferred to a seperatory funnel and the ether layer was washed twice with 50 ml. water, three times with 50 ml. portions of 10% sodium carbonate, and once again with 50 ml. water. The pH of the reulting wash was six. The ether was evaporated off at 100 mm. and slight heat. After four hours, five ml. benzene were added and distillation began at 1 mm. Four fractions were obtained. The first at b_1 29.5 - 32°, 1.6 ml.,fraction 2: b_1 32 - 54°, 1.0 ml., fraction 3: b_1 57-63° , 5.0 ml., fraction 4:

b_1 60° . Gas chromatography showed that there were four major compounds in fractions one through three, and six in fraction four.

Trial 2 - To 48.6 g.(0.32 mole) of diazoketone were added 54.8 g. anhydrous ether, then 57.8 g.(0.407 mole) of boron trifluoride etherate dropwise. Rapid evolution of gas occured and the reaction continued at room temperature for 34 minutes. The solution was transferred to a seperatory funnel and 50 ml. water were added. Two layers formed,which, on swirling, dissappeared and a homogeneous mixture formed. This mixture was allowed to stand for one and one-half hours to see if separation would occur. It did not. Instead a brown precipitate formed. The solution was filtered and washed with 50 ml. 10% sodium bicarbonate. There was release of gas and two layers reformed. The mixture was shaken for 15 seconds and the water layer was separated. It contained 78 ml. Washed with 50 ml. portions of bicabonate solution and obtained 121 ml. and 65 ml. water layers. The pH of the resulting wash water was six. Washed once with 50 ml. water, again with 50 ml. 10% sodium bicarbonate and again with water. The ether was distilled off with slight heat and vacuum for five hours. At the end of this time ten ml. benzene were added, and the benzene-water azeotrope was distilled off. This run was then combined with trial one and distilled on the spinning band column. Eleven fractions were obtained. Gas chromatographs were performed on all fractions and showed five major components and two minor ones. They were labeled 1,2a,2b,3, 4,5,6 respectively. The total yield was 24.47 g. with the following relative percentages: 1- 0.3%, 2a,b- 5.2%, 3- 64.1%, 4- 18.7%, 5,6- 0.01%. In addition, in fractions ten and eleven, there was apparently some decomposition of components 2a and 2b which accounted for 11.6% of the product formation.

Components 1 and 2b were unidentified. Component 2a was the hydroxy substituted ketone.

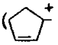
$\delta(CCl_4)$ 1.2-2.3(m, 2, e and f hydrogens), 2.3-2.8 (m, 4, h and i hydrogens), 2.8-3.8(m, 2, c and d hydrogens), 3.9-4.4(m, 1, g hydrogen), 5.82(s, 2, olefinic hydrogens), 11.64(s, 1, hydroxyl hydrogen).

$\nu\, CCl_4$ 2800-3200(broad, -OH), 3050(-CH=CH-, cis), 2930($-CH_2-$), 2850($-CH_2-$), 1710($>C=O$), 1610( $H-C=C-H$, (n) ,n=5), 1405($-CH_2-CO-$), 1210(-C-O-), 935(O-H).

Component 3 was the chloromethyl ketone

$\delta(CCl_4)$ 0.7-1.8(m, 2, e and f hydrogens), 1.8-2.2 (m, 2, c and d hydrogens), 2.2-2.5(m, 2, h hydrogens), 2.5-3.1(m, 1, g hydrogen), 3.99(s, 2, i hydrogens), 5.45 (s, 2, olefinic hydrogens).

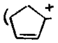
νCCl_4 3050(-CH=CH-,cis), 2940($-CH_2-$), 2850 ($-CH_2-$), 1720(>C=O), 1400($-CH_2-CO-$), 1080(>C=O).

mass spec. m/e 158 , (M^+-Cl) 123, (M^+-CH_2-Cl) 109, ($-CH_2^+$) 81, () 67.

Component 4 was the ethoxy substituted ketone.

δ (CCl_4) 1.0-2.1(t over m, 5, e,f, and k hydrogens), 2.1-2.5(m, 2, c and d hydrogens), 2.5-2.8(d, 2, h hydrogens), 2.8-3.2(m, 1, g hydrogen), 3.3-3.6(q, 2, j hydrogens), 3.7-4.0(d, 2, i hydrogens), 5.65(s, 2, olefinic hydrogens).

νCCl_4 3050(-CH=CH-, cis), 2980($-CH_3$), 2935($-CH_2-$), 2900($-\overset{|}{C}H-$), 2850($-CH_2-$), 1720(>C=O), 1615($^{H}\underbrace{C=C}_{n}{}^{H}$, n=5), 1460($-CH_3$), 1400($-CH_2-CO-$), 1335($-\overset{|}{C}H-$), 1105(-C-O-C-).

mass spec. m/e 168, ($M^+-OCH_2CH_3$) 123, ($M^+- CH_2OCH_2CH_3$) 109, ($-CH_2^+$) 81, () 67.

Trial 3 - To the diazoketone of batch six (0.106 mole) was added 16.6 g.(0.117 mole) of boron trifluoride etherate dropwise. The exothermic reaction was carried out at room temperature with rapid evolution of a gas. The solution was reacted for 40 minutes then transfered to a seperatory funnel and washed once with 50 ml. 10%

sodium bicarbonate. There was separation of layers and release of gas. The ether layer was washed once with 50 ml. water and the layers separated, but the black product layer tarred up and separation or distillation was not possible. A molecular weight determination showed that the tar was a polymer with a range of 750-950 g./mole.

X. Synthesis of thiophenoxyacetyl methyldiazoketone

Batch 1 - To the diazomethane of batch six, was added 24.2 g.(0.13 mole) of thiophenoxyacetyl chloride, dropwise. There was evolution of gas and the mixture was allowed to stand in an ice bath for twelve hours. The ether was evaporated off and sodium sulfate was added to dry the diazoketone. The solution was filtered. The yield was 33.5 g. of which 40% was ether. Actual yield was 13.4 g.(57%).

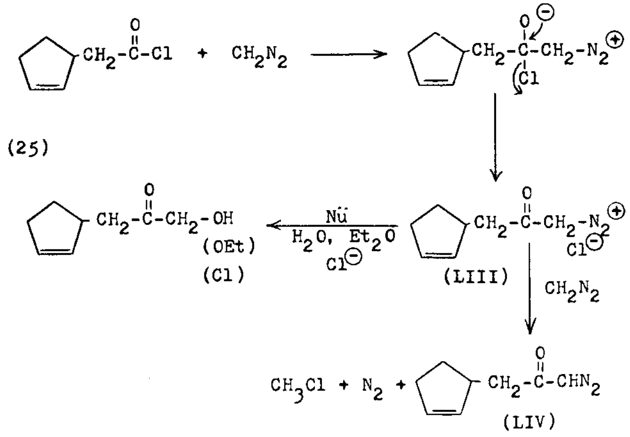
XI. Reaction of thiophenoxyacetyl methyldiazoketone with boron trifluoride and nitromethane

Trial 1 - To the diazoketone from batch one, above, was added 8.55 ml.(0.13 mole) nitromethane and then 15.27 g. (1.5 equivalents) of boron trifluoride, drop wise. There was a vigorous evolution of gas and the solution turned from clear yellow to opaque brown-black. The mixture was allowed to react at room temperature for 35 minutes. It was then transferred to a seperatory funnel and washed once with 50 ml. water, twice with 25 ml. portions of 10% sodium bicarbonate, then once with 15 ml. 10% sodium bicarbonate. The pH of the resulting wash water was eight. The solution was then transferred to a flask and heated slightly under slight vacuum for four hours. Then four ml. of benzene were added and the distillation continued under nitrogen at nine mm. After the azeotrope was collected, a distillation at 1 mm. was attempted. Nothing distilled over after gradually raising the temperature to 65° . All the material in the flask turned into a solid black tar.

DISCUSSION of EXPERIMENTAL RESULTS

Analysis of the reaction products from the ether and nitromethane runs produced some unexpected results. Of the greatest interest to us was the existence of 64% of the ether reaction products being the chloromethyl ketone of 2-cyclopentene-1-acetic acid. The hydroxy and ethoxy homologues were expected and found, but their percentages were also larger than anticipated.

To account for the formation of all three, a diazonium salt intermediate is proposed. In this case, the addition of the acid chloride to the diazomethane (25) produces, initially, the salt (LIII).



What normally happens at this point is that the excess diazomethane abstracts an acidic diazomethyl hydrogen to form the diazoketone (LIV) and the attack by the chloride ion gives chloromethane and nitrogen.

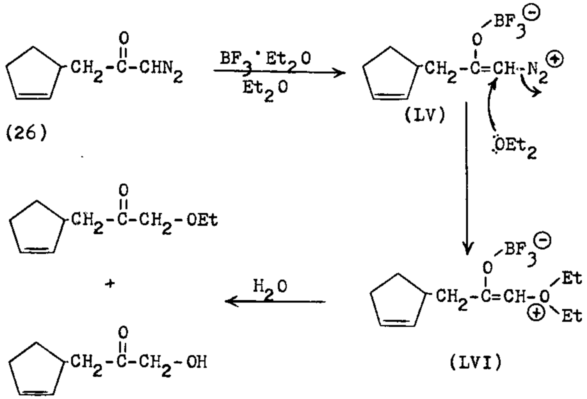
However, what we have here is not a normal system. Instead, our 5,6 double bond is in some was participating to destabilize the N_2 leaving group and causing it to leave prior to further attack by diazomethane. In this case, any nucleophile present in the reaction mixture could react and produce any of the substituted products.

The chloride ion has the best chance for attack since it is in the immediate vicinity as the anion of the salt. Ether can likewise attack due to the fact that the diazomethane is in an ether solution. There is water present too, from the aqueous sodium hydroxide catalyst used in the decomposition of the diazomethane precurser. In the last two, it is the non-bonding pairs of electrons on oxygen that are serving as the nucleophiles in the displacement of the nitrogen leaving group.

The NMR spectrum taken of the diazoketone mixture supported this theory since it showed that the product was not completely diazoketone, but was in fact, partially composed of the chloroketone.

As just mentioned though, there was some diazoketone formation. When the diazoketone was reacted with the boron trifluoride etherate and solvent, the hydroxy and ethoxy compounds were produced, as well as a polymer.

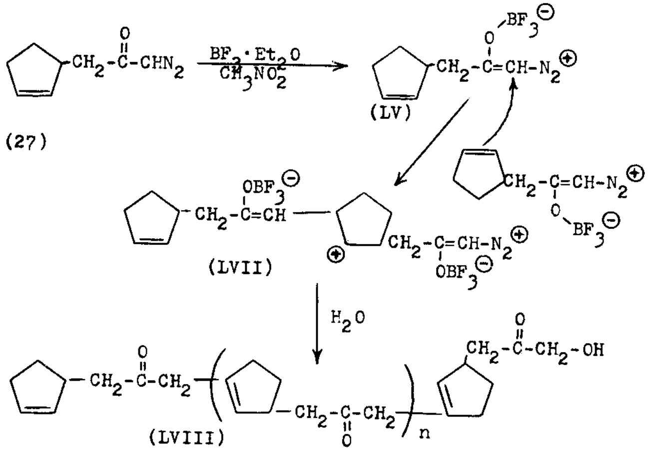
When the solvent was diethyl ether, there was very little polymer formation but a substantial amount of the hydroxy and ethoxy substituted products (26).



What most likely happened was the boron trifluoride complexed with the carbonyl oxygen in the diazoketone producing (LV) as was expected. Then the ether solvent, acting as a nucleophile, attacked the diazomethyl carbon, displacing nitrogen and forming an oxonium ion (LVI). With the ether solvent, any chance for π bond participation was practically ruled out. The strongly nucleophilic ether would dominate over the double bond in a competition reaction.

Subsequent hydrolysis broke the oxygen-boron bond and cleavage of the oxonium ion resulted. When the break occurred between the oxygen-ethyl bond, the ethoxy compound resulted. Breaking the oxygen-carbon bond gave the carbocation which was then attacked by water giving the hydroxy product.

When nitromethane was used as the solvent, the polymer was the major product (27).



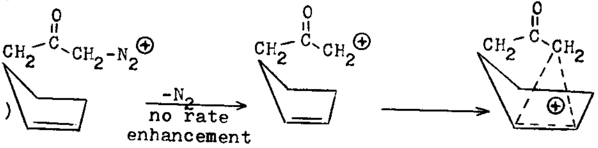
There were small amounts of distillable products- the three substituted ones as found in the ether runs- which were formed in the manner already outlined.

What occurred to form the polymer was acid catalyzed cationic polymerization. On treatment with boron trifluoride etherate and nitromethane, the diazoketone again yielded (LV). But nitromethane is a relatively poor nucleophile so no intermediate comparable to the oxonium ion was not produced. Instead the double bond acted as a nucleophile, but not in the manner hoped for. Rather, the reaction was an intramolecular π bond attack to give (LVII). This reaction is the propogation step in the polymerization scheme. The boron trifluoride is a Lewis acid and serves as the catalyst, and the highly polar nitromethane enhances the cationic reaction to give the polymer (LVIII).

Molecular weight determination of the polymer indicated its weight was 750-950 g./mole, which corresponds to a chain of six to eight units. The infra-red spectrum also supported this theory since there was evidence for a ${}^{R}_{R}\!>\!C{=}C\!<^{H}_{R}$ bond at 855 cm^{-1} .

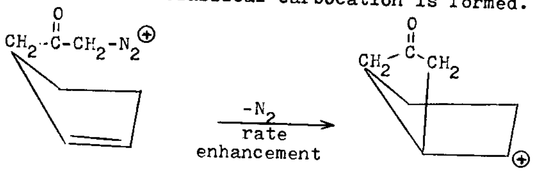
There are four general cases of reactions that can occur with a π system and a diazoketone as outlined below.

(28)



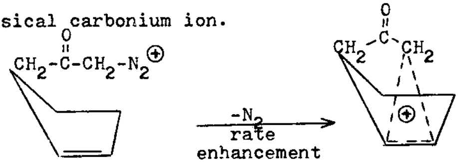
In (28) the leaving group may depart without assistance, and the non-classical carbocation is formed.

(29)



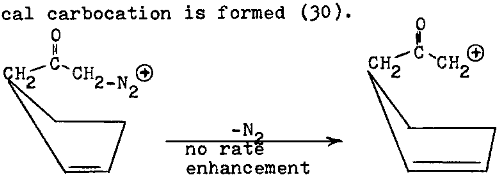
The second possibility (29) is rate enhancement through π bond participation, but the intermediate is a classical carbonium ion.

(30)



Another possibility is rate enhancement when a non-classical carbocation is formed (30).

(31)



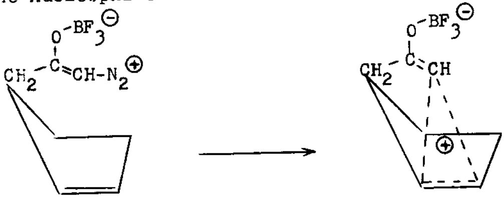
Finally, there is no rate enhancement in (31) and a classical carbonium ion is formed.

In the first (28) and third (30) cases, there is the possibility of nucleophilic attack at any of three positions to give the substitution products, the only difference being in the rate of substitution. The second case (29) would lead to ring substituted products, of which none were identified, so this mechanism is eliminated as a possibility for our system. The last case (31) would give only chain substituted compounds with the double bond having no effect on the rate of substitution.

When the reactions were run with ether solvent, the products isolated argued against (29), but the unusual chloroketone formation could be explained by (30), occuring before the addition of the Lewis acid.

Before the Lewis acid was added, the reaction would be as in (30), with chloride ion, water, and ether attacking as nucleophiles. After boron trifluoride was added, the only difference occurring in the reaction from (30) is that the acid is coupled with the oxygen as in (32), and the nucleophiles are water, and ether.

(32)



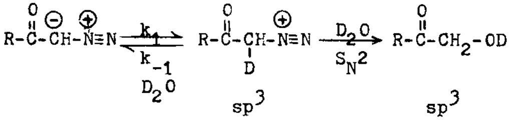
However, (31) would also explain product formation after the boron trifluoride was added since the rate is not necessarily enhances after the addition of acid. For that matter, (28) might also be considered but for the fact that one might expect to find some trace of ring substituted products, which we did not.

In the cases where the nitromethane was employed as the solvent, path (31) would explain the polymer formation, and nitromethane, being a polar solvent, accelerates this pathway. There were the chloro, hydroxy, and ethoxy substituted products formed in small amounts but these were formed before the acid or solvent were added, as in the ether case. Once the carbonium ion was formed, the intermolecular π bond attack proceeded as mentioned earlier.

In the run where the ether to acid chloride ratio was four-to-one, there was complete conversion of the acid chloride to diazoketone, with the chloride ion taken care of as chloromethane. On addition of the acid, the classical carbonium ion of reaction (31) was produced.

One way of determining the mechanism is through kinetic studies. In normal cases of the reaction of a diazoketone with a Lewis acid and suitable solvent, we initially have fast reversible protonation (with a Lewis acid we do not have protonation but a step analogous to this) to give the sp^3 hybridized intermediate (33).

(33)



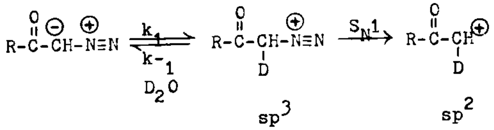
$$R-\overset{O}{\overset{\|}{C}}-\overset{\ominus}{C}H-\overset{\oplus}{N}\equiv N \underset{\substack{k_{-1}\\ D_2O}}{\overset{k_1}{\rightleftharpoons}} \underset{sp^3}{R-\overset{O}{\overset{\|}{C}}-\underset{D}{\underset{|}{C}}H-\overset{\oplus}{N}\equiv N} \xrightarrow[S_N2]{D_2O} \underset{sp^3}{R-\overset{O}{\overset{\|}{C}}-CH_2-OD}$$

Then, in the rate determining step, an S_N2 substitution reaction occurs, giving the product. We notice here that the k_{H_2O}/k_{D_2O} ratio is less than one due to the kinetic isotope effect.

But, if we have participation by the double bond in the R group, the picture changes (34). There is still fast reversible protonation to give the sp^3 hybridized intermediate, but the double bond assists the nitrogen leaving group, in the next step, to leave sooner than normal, producing an sp^2 hybridized species via an

S_N1 mechanism.

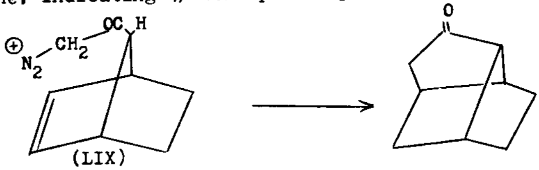
(34)



$$R\text{-}\overset{O}{\overset{\|}{C}}\text{-}\overset{\ominus}{C}H\text{-}\overset{\oplus}{N}{\equiv}N \underset{\underset{D_2O}{k_{-1}}}{\overset{k_1}{\rightleftharpoons}} \underset{sp^3}{R\text{-}\overset{O}{\overset{\|}{C}}\text{-}\underset{D}{C}H\text{-}\overset{\oplus}{N}{\equiv}N} \xrightarrow{S_N1} \underset{sp^2}{R\text{-}\overset{O}{\overset{\|}{C}}\text{-}\underset{D}{C}H^{\oplus}}$$

Here we have a k_{H_2O} / k_{D_2O} ratio greater than one due to a secondary isotope effect.

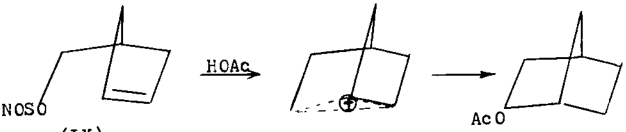
A specific example of this is shown is some work done by Dahn and others[15]. They found that (LIX), also a 5,6 double bond, had a k_{H_2O} / k_{D_2O} ratio greater than one, indicating π bond participation.



(LIX)

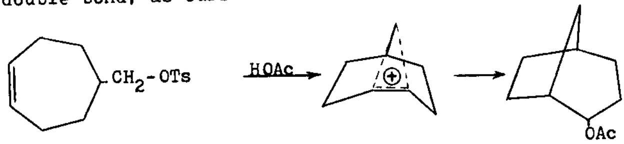
In various other compounds, where he varied the ring substituents and the position of the carbon-carbon double bond, the k_{H_2O} / k_{D_2O} ratio was less than one, indicating little or no participation. In addition, the hydrolysis rate constants for this compound were on the order of 500 to 1000 times greater than those for the others.

Solvolysis rate studies could also help in determining the mechanism. Lawton[34] found that $2(\Delta^3$-cyclopentenyl) ethyl p-nitrobenzene sulfonate (LX) had an acetolysis rate 95 times that of the saturated compound.



(LX)

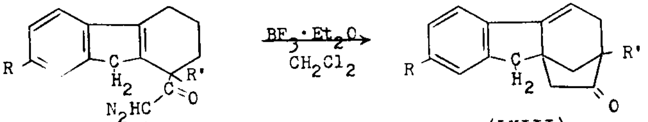
He also found that the intermediate was the non-classical carbonium ion, as was found when ^{4}-cycloheptenyl methyl-p-toluene sulfonate (LXI) was solvolyzed [35]. In the latter case, the acetolysis rate was 35 times that of the model, saturated compound. Note that both of these unsaturated molecules contain the 5,6 double bond, as ours did.



(LXI)

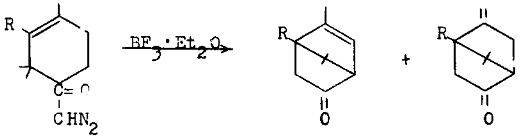
While none of the products analyzed turned out to be the pentalenones we thought would be produced, there is evidence for this type of ring closure besides Smith, Branca, and Toders work [1].

Chakrabortty and others [36] obtained ring closure from a 5,6 carbon-carbon double bond attack in (LXII) to give (LXIII).



(LXII) (LXIII)

Erman and Stone [37] did likewise with (LXIV) yielding (LXV) and (LXVI).



(LXIV) (LXV) (LXVI)

Both of these proceeded through a tertiary carbonium ion and it appears reasonable that this stabilized carbocation is a large factor in determining the success of π bond attack.

The white precipitate formed in the diazoketone syntheses was polyethylene. This was confirmed by a sharp singlet at 1.96 δ in the NMR spectra of the diazoketone solutions. It was formed from the polymerization of diazomethane.

In the formation of the acid chlorides of 2-cyclopentene-1-acetic acid and thiophenoxyacetic acid, it was found that the reaction of the thionyl chloride with the acid proceeded with a better yield at room temperature rather than with refluxing.

The reaction of the thiophenoxyacetyl chloride with diazomethane appeared, from the NMR, to have produced the diazoketone. However, reaction of the diazoketone with boron triflouride etherate and nitromethane gave a black tarry polymer. Presumably a mechanism similar to that for the polymer formation in the cyclopentene reaction occurred; an acid catalyzed cationic polymerization.

SUGGESTIONS FOR FURTHER WORK

1) Most importantly, kinetic rate studies need to be performed on the cyclopentene diazoketone reactions as well as several others similar in nature to see, if in fact, there is rate enhancement and participation.

2) Use only one equivalent of diazomethane when preparing the diazoketone, but have one equivalent of triethyl amine present to take care of the hydrogen chloride produced.

3) When the acid chloride is added to the diazomethane solution, this should be accompanied by careful, but thorough, stirring of the mixture. This may insure that the excess diazomethane or triethyl amine will react with the hydrogen chloride.

4) Analyze the diazoketone solution for product formation. See if there are any of the substituted products present.

5) Rather than bubbling nitrogen through the reaction vessel during distillation, use a hot plate/stirrer combination. Also a small distillation apparatus with a short run to the condenser or a heated column to the condenser would be helpful.

APPENDIX A
Instrumentation

NMR's were run on a Hitachi Perkin-Elmer R-24A High Resolution NMR Spectrometer at 60 Hz.

IR spectra were taken on a Perkin-Elmer 727 Infrared Spectrophotometer.

Molecular weights were obtained from a Perkin-Elmer Molecular Weight Apparatus - Model 115 (Vapor Phase Osmometer).

Gas Chromatographs were run on a Gow Mac Gas Chromatograph - Series 550 Thermal Conductivity Detector with helium carrier gas on a six foot silicone column.

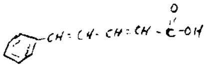
APPENDIX B

Infrared Spectra

SAMPLE

SPECTRUM NO. 6

REMARKS



ORIGIN

PURITY

SPEED NORMAL X FAST

SLITS NORMAL X WIDE

PHASE

CONCENTRATION

THICKNESS 0.1mm

DATE 2/4/78

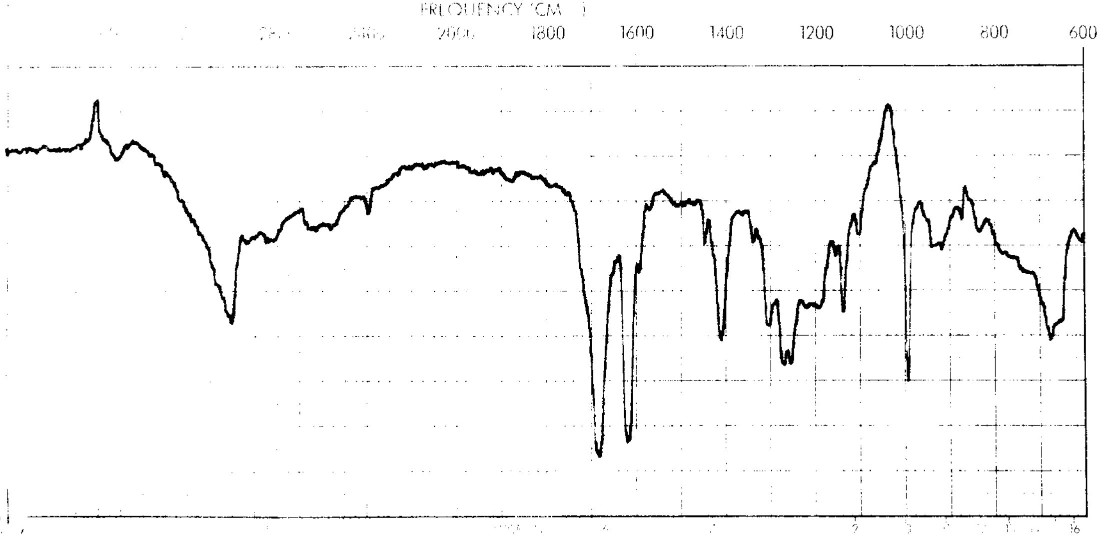
OPERATOR R.J. Perry

RECORDING CHARTS

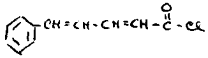
SPECTRUM NO.

SAMPLE 1 5-PHENYL-2,4-PENTADIENOIC ACID

SAMPLE 2



REMARKS



ORIGIN

PURITY

SPEED NORMAL X FAST

SLITS NORMAL X WIDE

PHASE

CONCENTRATION 3%

THICKNESS 0.1mm

DATE 1/10/78

OPERATOR R. J. Perry

RECORDING CHARTS

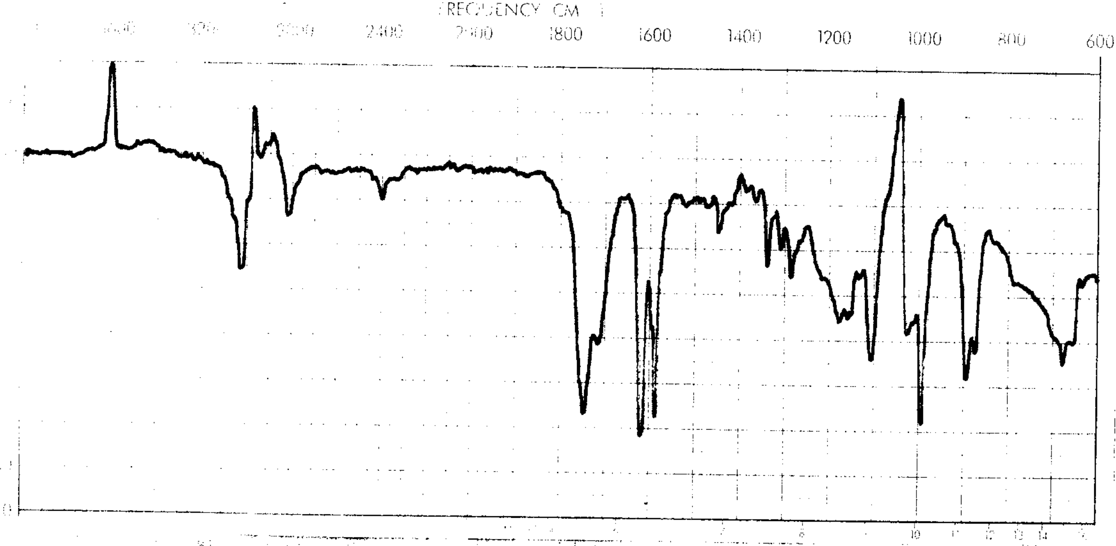
SPECTRUM NO.

SAMPLE 1 5-PHENYL-2,4-PENTADIENOIC ACID CHLORIDE

SAMPLE 2

SAMPLE

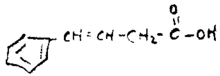
SPECTRUM NO. 57



SAMPLE

SPECTRUM NO. 66

REMARKS



ORIGIN

PURITY

SPEED NORMAL ☒ FAST

SLITS NORMAL ☒ WIDE

PHASE

CONCENTRATION

THICKNESS 0.1mm

DATE 2/1/78

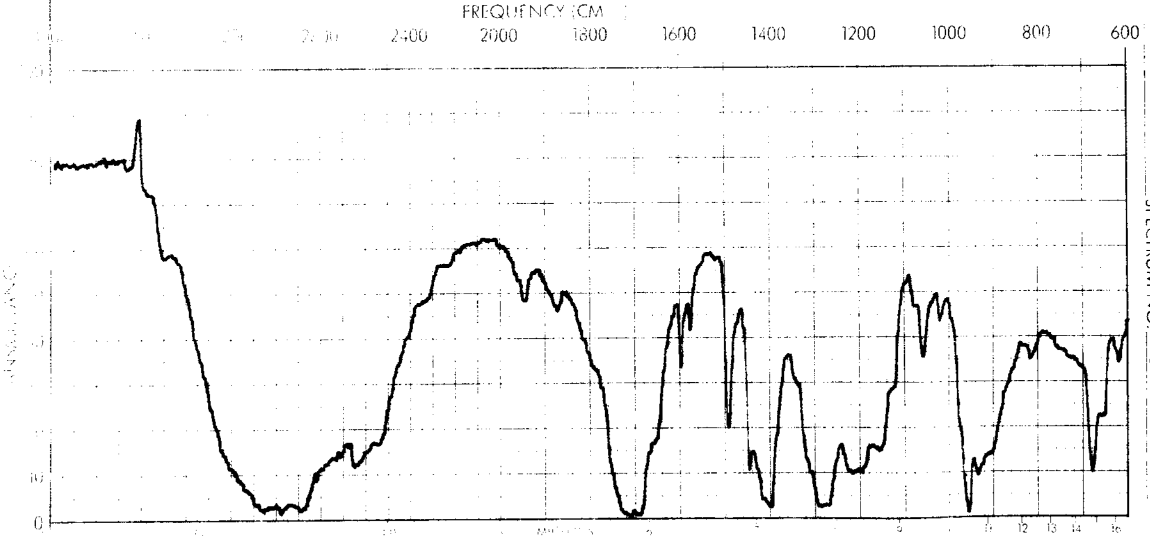
OPERATOR R. Ray

RECORDING CHARTS

SPECTRUM NO.

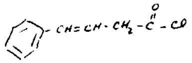
SAMPLE 1 STYRYLACETIC ACID

SAMPLE 2



RECORDING CHARTS

REMARKS



ORIGIN____

PURITY 95%

SPEED NORMAL ☒ FAST

SLITS NORMAL ☒ WIDE

PHASE

CONCENTRATION

THICKNESS 0.1mm

DATE 1/3/78

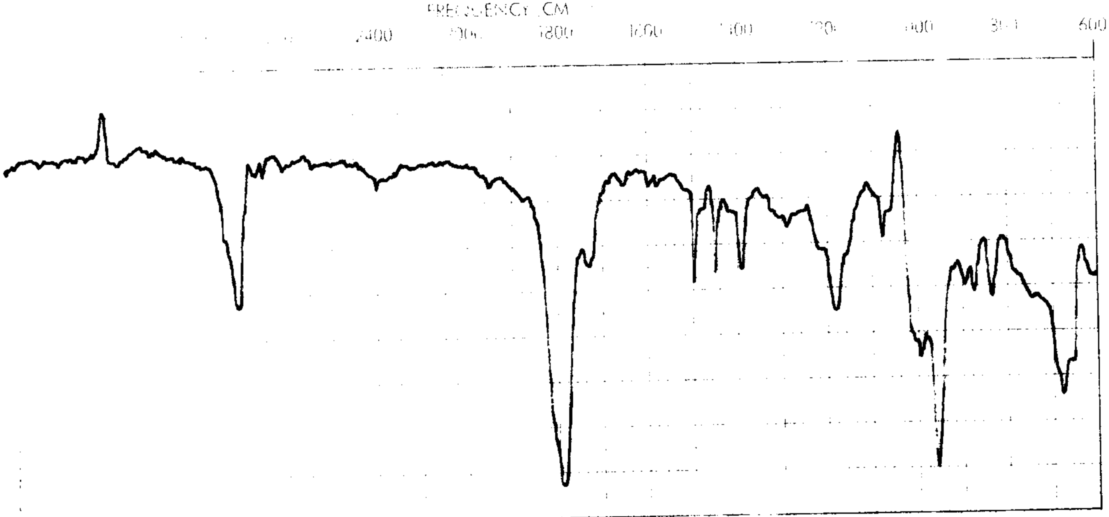
OPERATOR P. J. Perry

SPECTRUM NO.

SAMPLE 1 STYRYLACETYL CHLORIDE

SAMPLE 2

SAMPLE



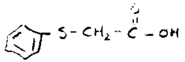
SPECTRUM NO. 48

57

SAMPLE

SPECTRUM NO. 67

REMARKS



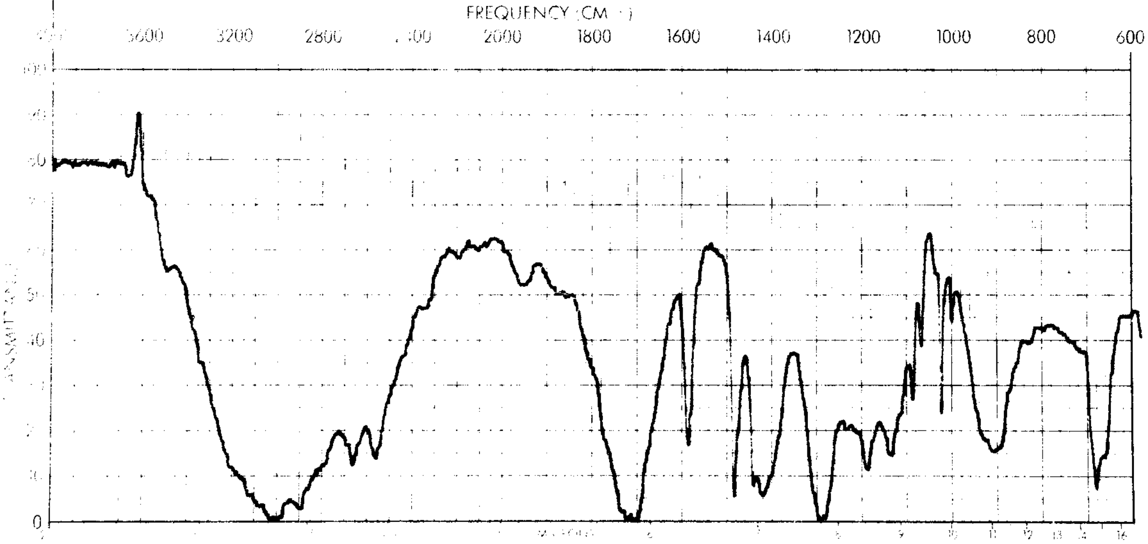
ORIGIN
PURITY

SPEED NORMAL X FAST
SLITS NORMAL X WIDE
PHASE
CONCENTRATION
THICKNESS 0.1mm
DATE 2/4/78
OPERATOR R. J. Berry

G RECORDING CHARTS

SPECTRUM NO.
SAMPLE 1 THIOPHENOXYACETIC ACID

SAMPLE 2



SAMPLE

SPECTRUM NO. 50

©RECORDING CHARTS

SPECTRUM NO.

SAMPLE 1 THIOPHENOXYACETYL CHLORIDE

SAMPLE 2

ORIGIN

PURITY 99+ %

SPEED NORMAL ☒ FAST

SLITS NORMAL ☒ WIDE

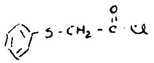
CONCENTRATION 2%

THICKNESS 0.1mm

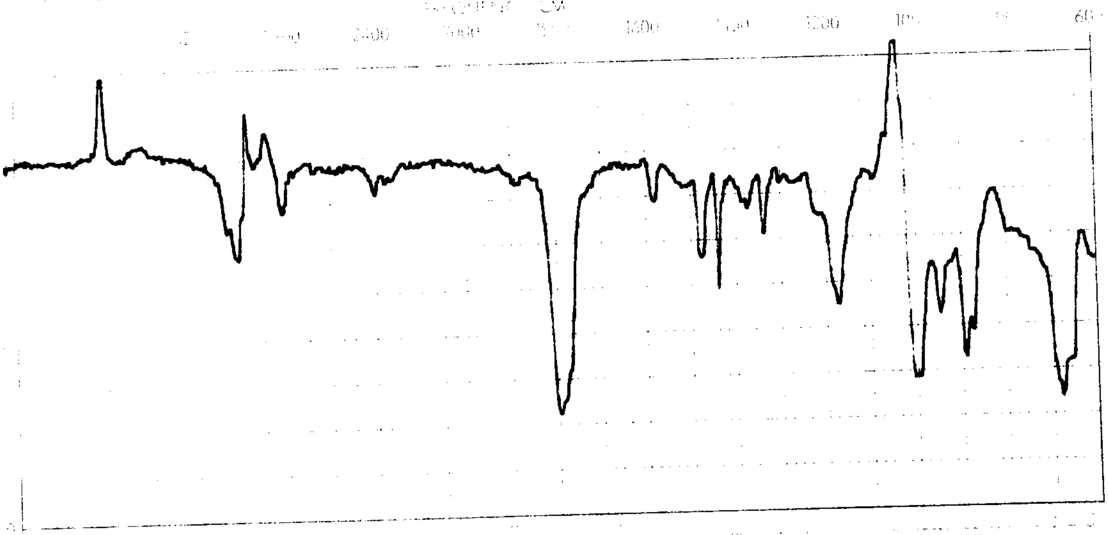
DATE 1/3/78

OPERATOR R.J. Perry

REMARKS

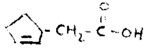


$C_6H_5-S-CH_2-\overset{O}{\overset{\|}{C}}-Cl$



007 196

REMARKS



ORIGIN

PURITY

SPEED NORMAL X FAST

SLITS NORMAL X WIDE

PHASE

CONCENTRATION 2%

THICKNESS 0.1mm

DATE 2/4/78

OPERATOR R J Remy

RECORDING CHARTS
GRAPHIC CONTROLS CORPORATION
BUFFALO, NEW YORK

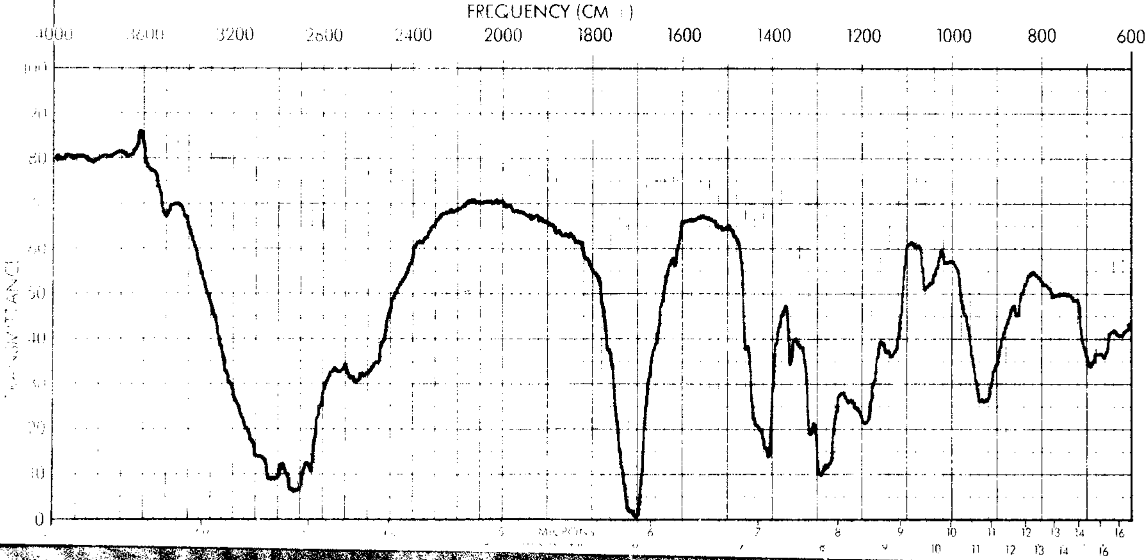
SPECTRUM NO.

SAMPLE 1 2-Cyclopentene-1-acetic acid

SAMPLE 2

SAMPLE

SPECTRUM NO. 05 60



SAMPLE

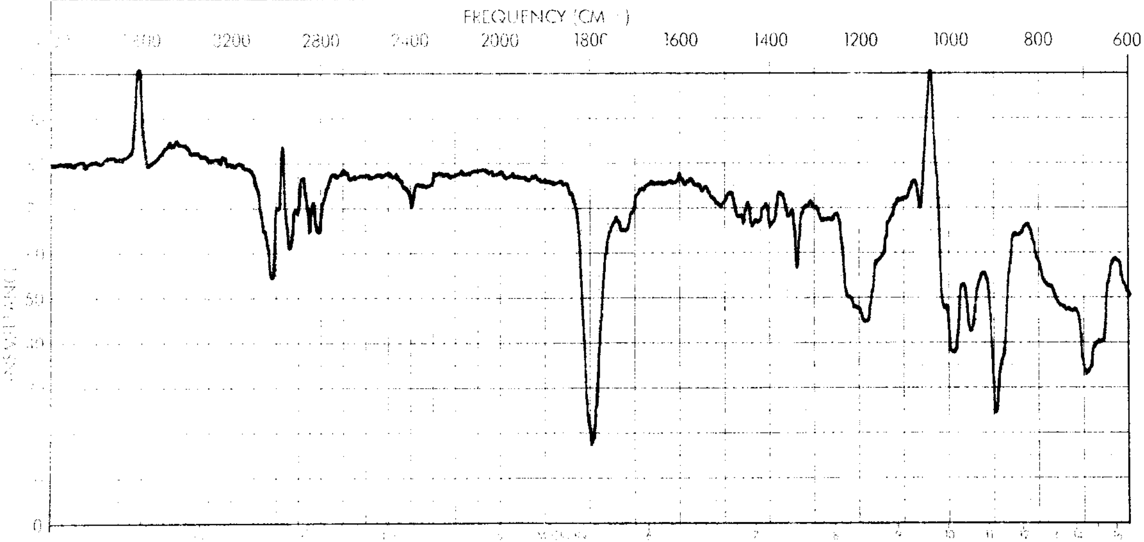
SPECTRUM NO. 62

REMARKS

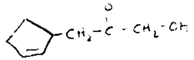
ORIGIN
PURITY
SPEED NORMAL X FAST
SLITS NORMAL X WIDE
PHASE
CONCENTRATION 2%
THICKNESS
DATE 1/25/78
OPERATOR R.J. Perry

RECORDING CHARTS

SPECTRUM NO
SAMPLE 1 2-Cyclopentene-1-Acetyl Chloride
SAMPLE 2



REMARKS



ORIGIN

PURITY

SPEED ☒ NORMAL FAST

SLITS ☒ NORMAL WIDE

PHASE

CONCENTRATION

THICKNESS 0.1mm

DATE 2/25/78

OPERATOR

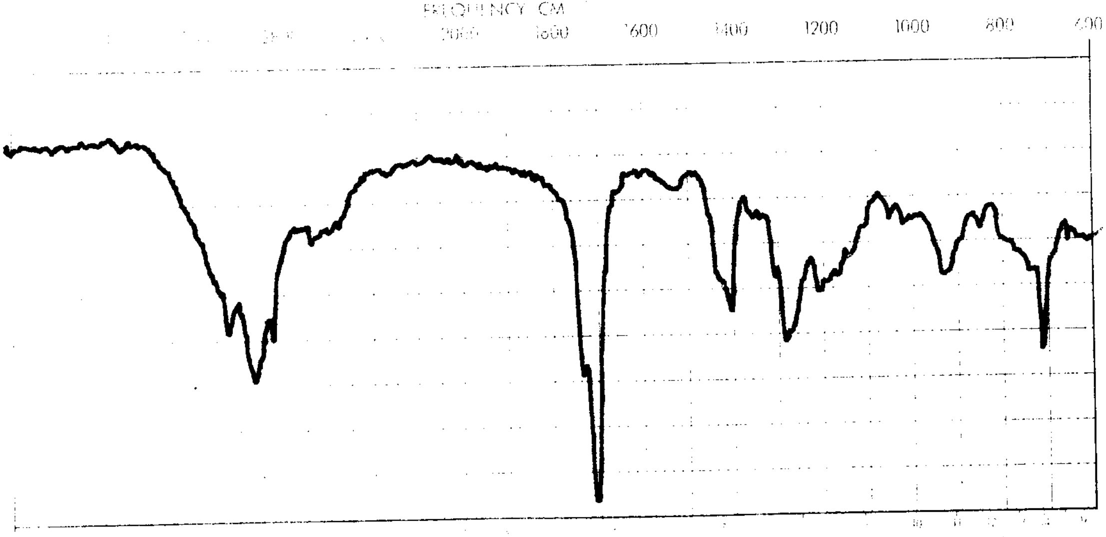
RECORDING CHARTS

SPECTRUM NO.

SAMPLE 1 compound C.

SAMPLE 2

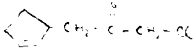
SAMPLE



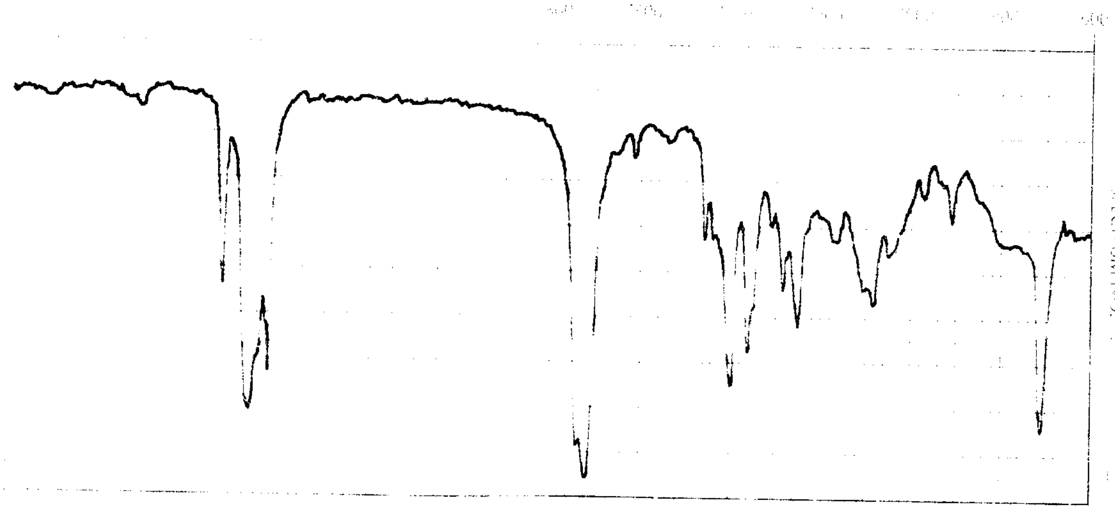
SPECTRUM NO. 73 62

UN82 PERRY, R.J. REACTIONS OF DIAZOKETONES WITH, ETC.
P464r/1978 Chemistry HRS. 3/78 2 of 2

SAMPLE



$CH_2-\overset{O}{\overset{\|}{C}}-CH_2-Cl$



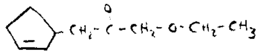
SPECTRUM NO. [illegible]

SAMPLE

SPECTRUM NO. 11

64

REMARKS



ORIGIN

PURITY

SPEED [✓ NORMAL] FAST

SLITS [✓ NORMAL] WIDE

PHASE

CONCENTRATION

THICKNESS

DATE

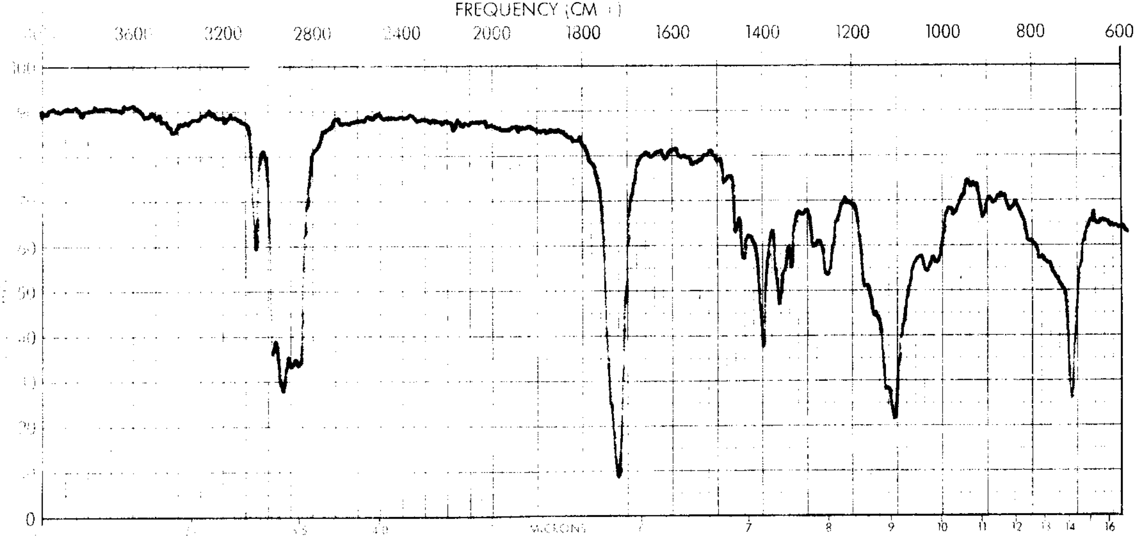
OPERATOR

RECORDING CHARTS

SPECTRUM NO.

SAMPLE 1 COMPONENT 4

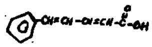
SAMPLE 2



APPENDIX C

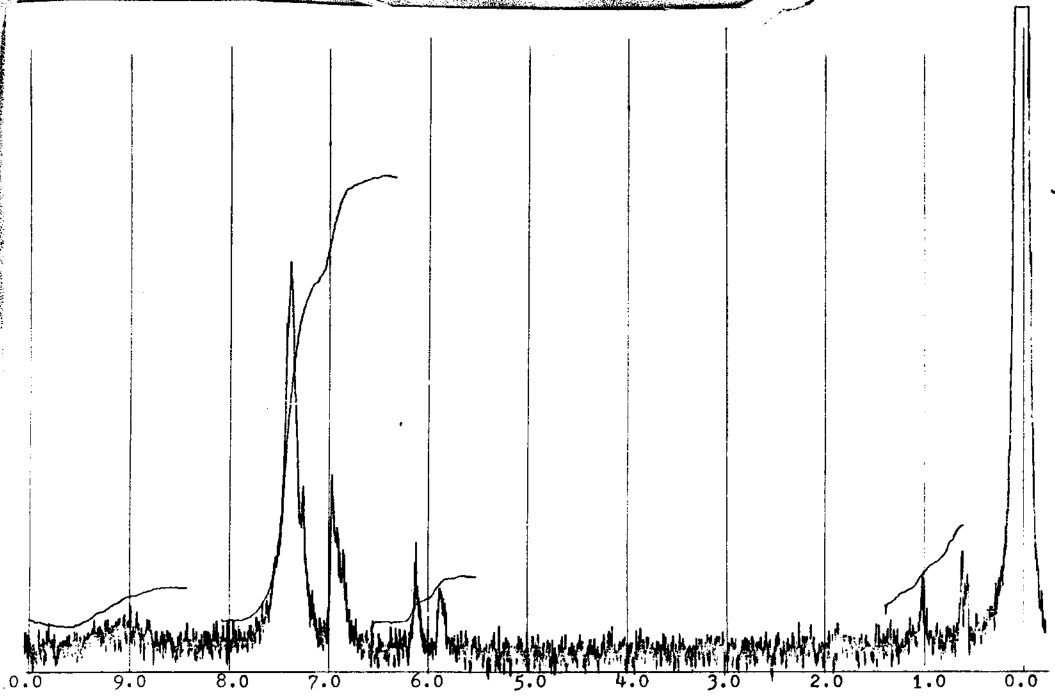
NMR Spectra

3

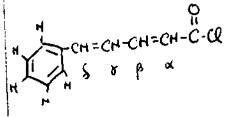


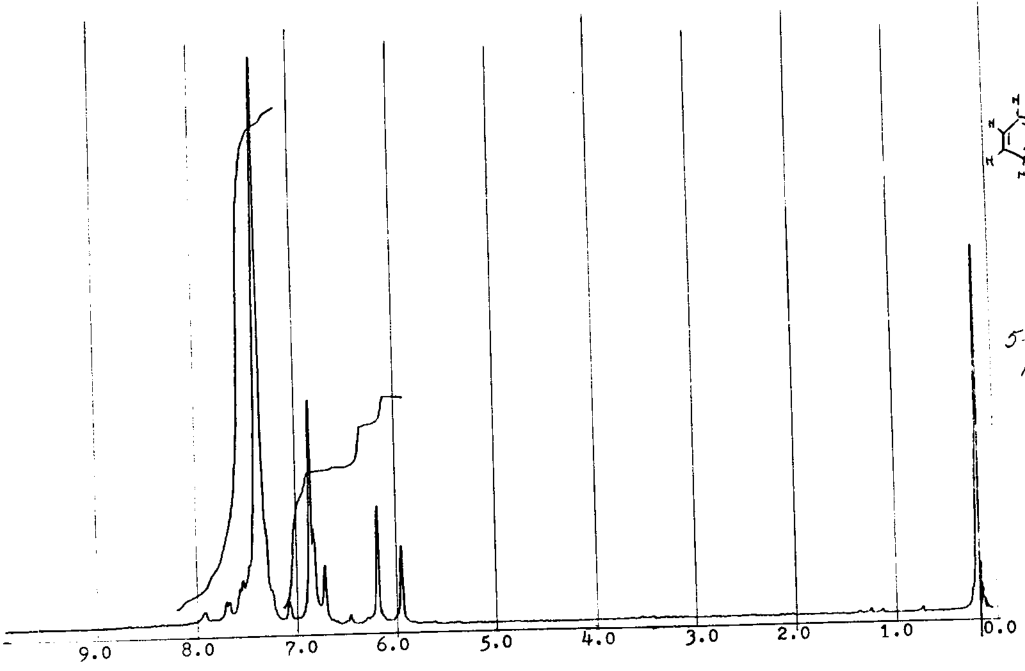
$-CH=CH-CH=CH-\overset{O}{\overset{\|}{C}}-OH$

5-phenyl-2,4-pentadienoic acid



15

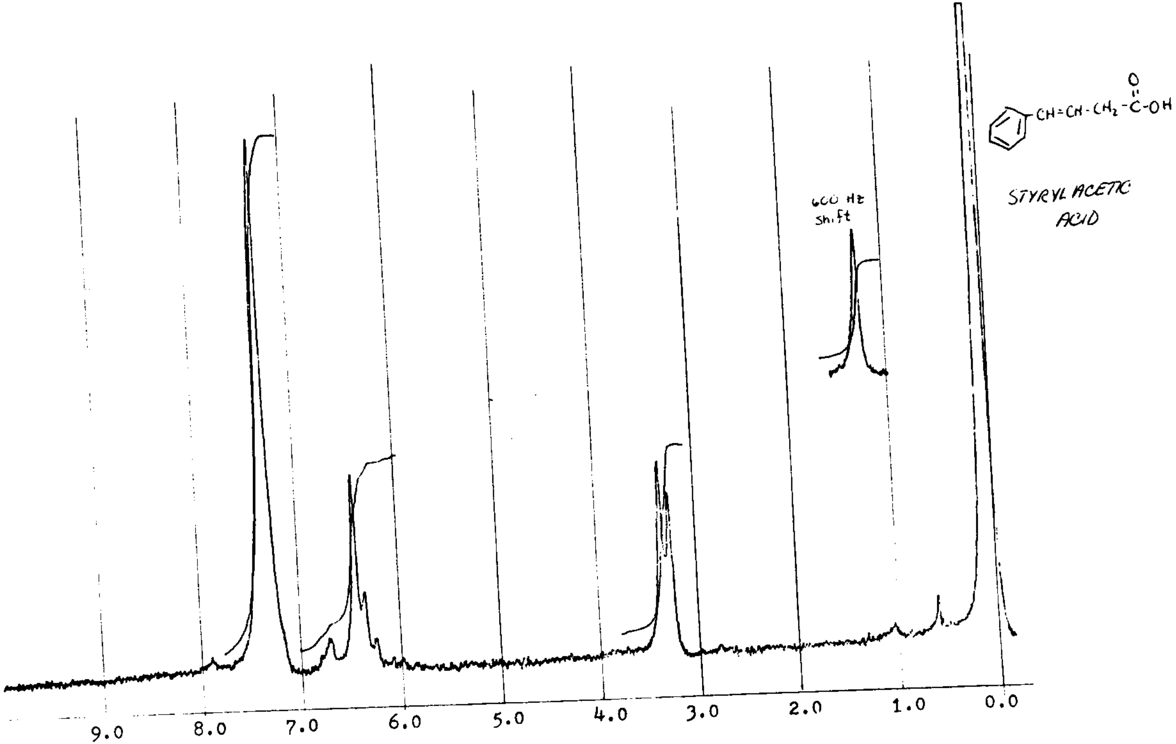


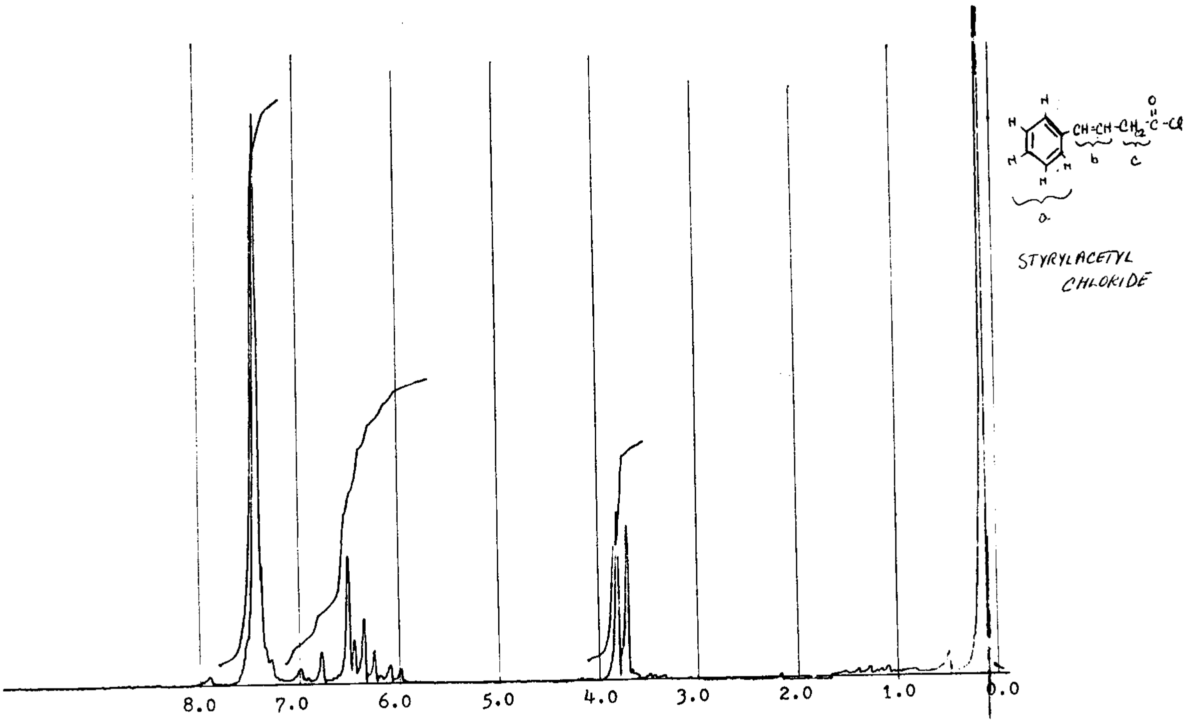


5-phenyl-2,4-
pentadienoic
acid chloride

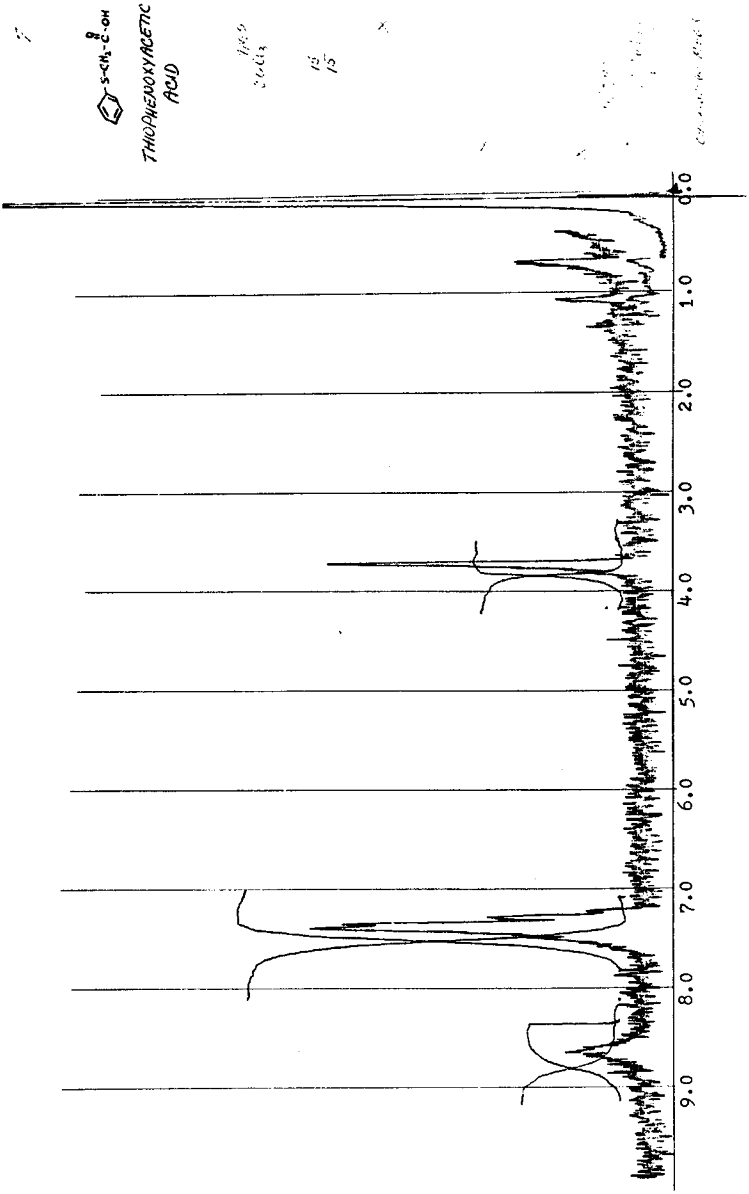
[illegible]

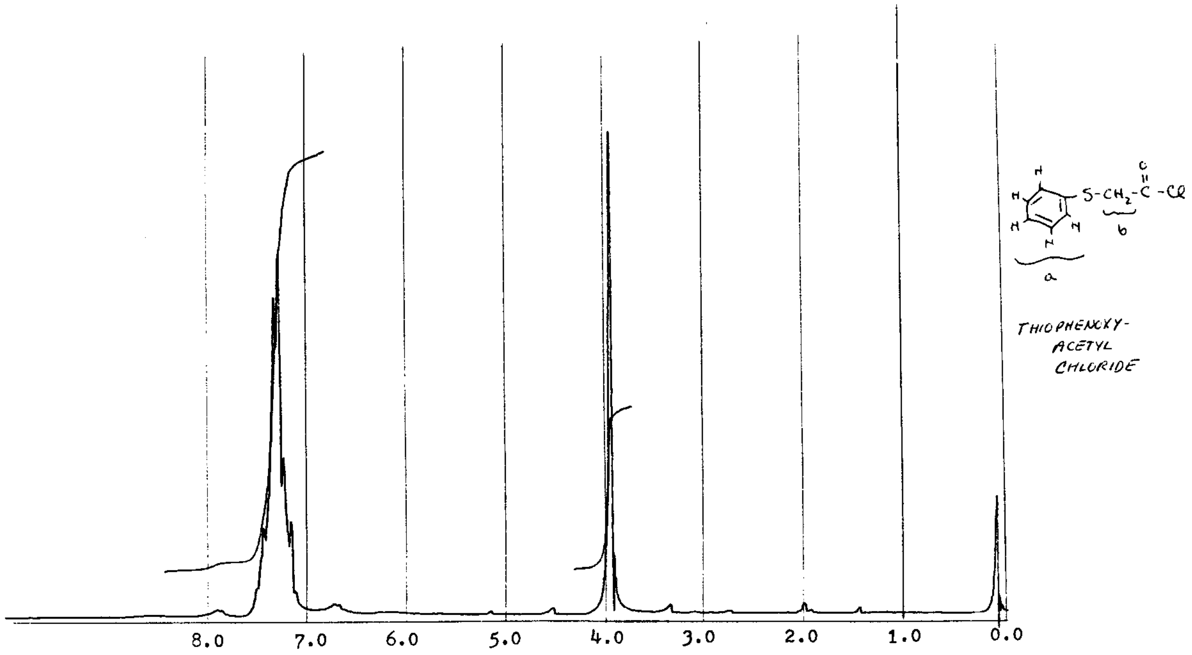
[illegible]

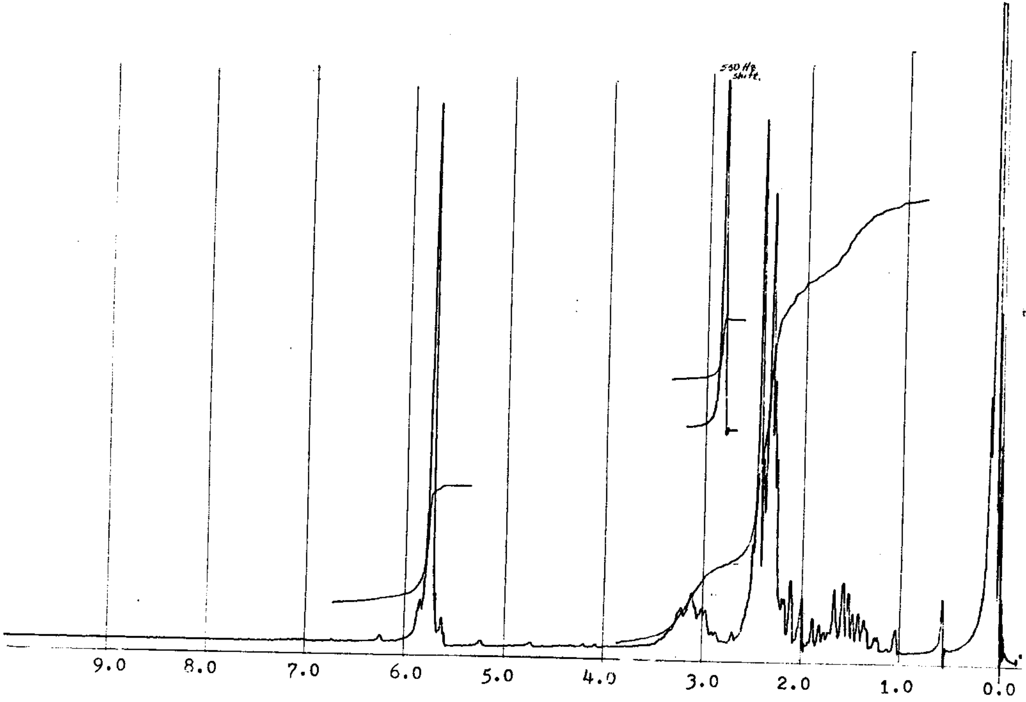

STYRYL ACETIC ACID



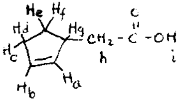
STYRYLACETYL
CHLORIDE


S-CH₂-C-OH
THIOPHENOXYACETIC ACID
CDCl₃
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0


S-CH₂-C(=O)-Cl
a
b
THIOPHENOXY-
ACETYL
CHLORIDE
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0

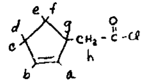


2-cyclopentene-1-acetic acid

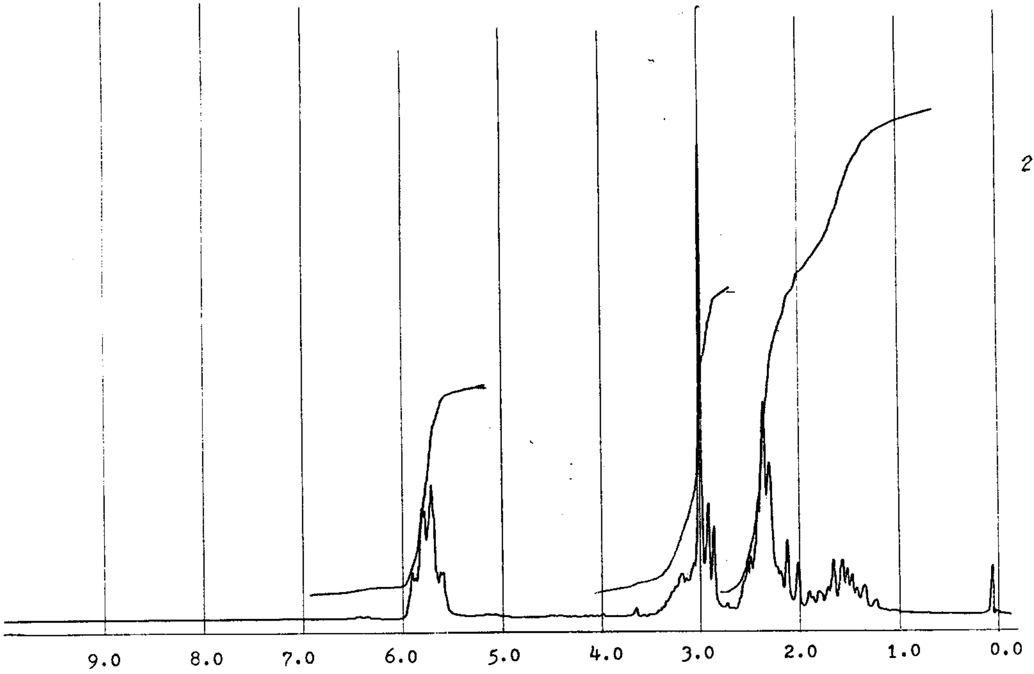


5/x/77

4

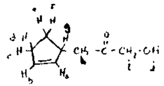


2-cyclopentene-1-
acetyl chloride

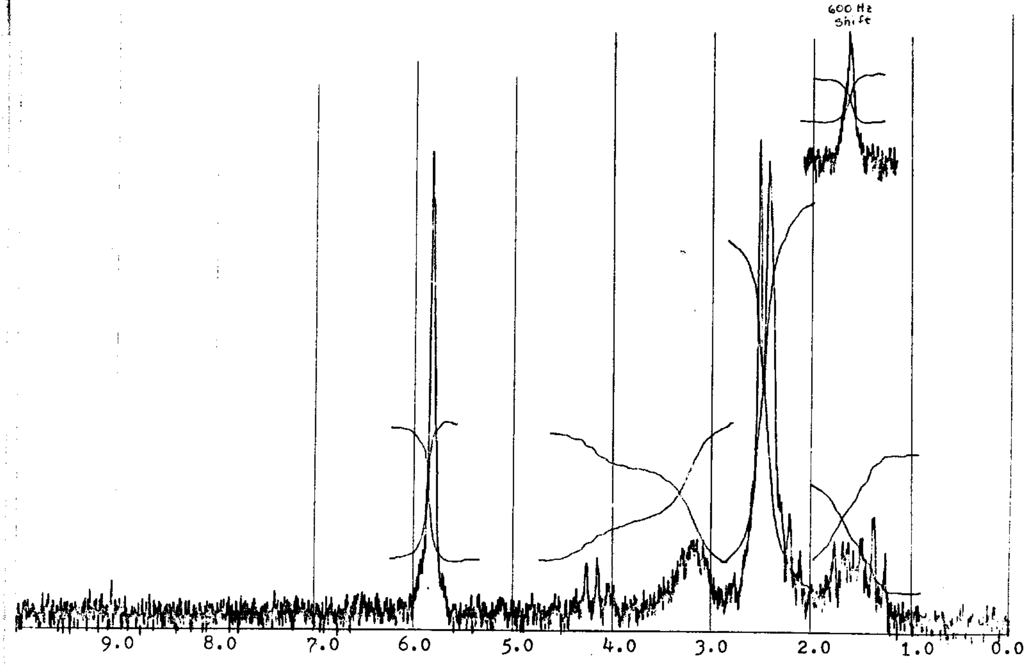


32

COMPONENT 2a

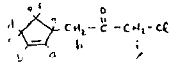


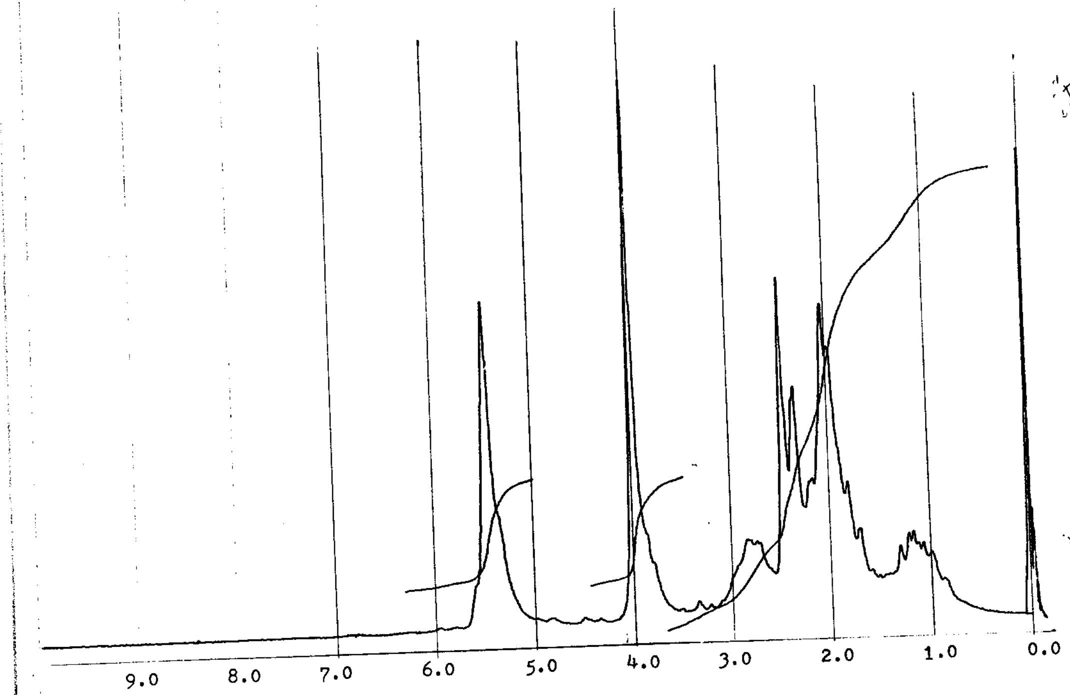
CCl4



i6

COMPONENT 3





6
2

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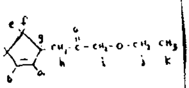
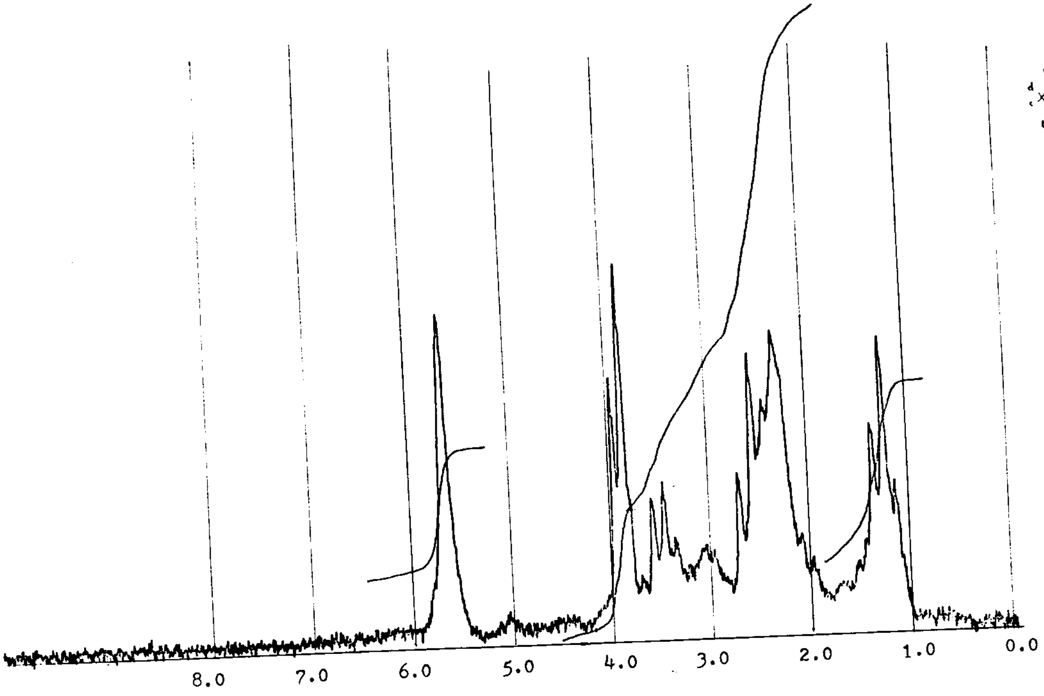
R J Perry

COMPONENT A



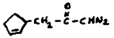
CCl4

15
16



23

BATCH 5



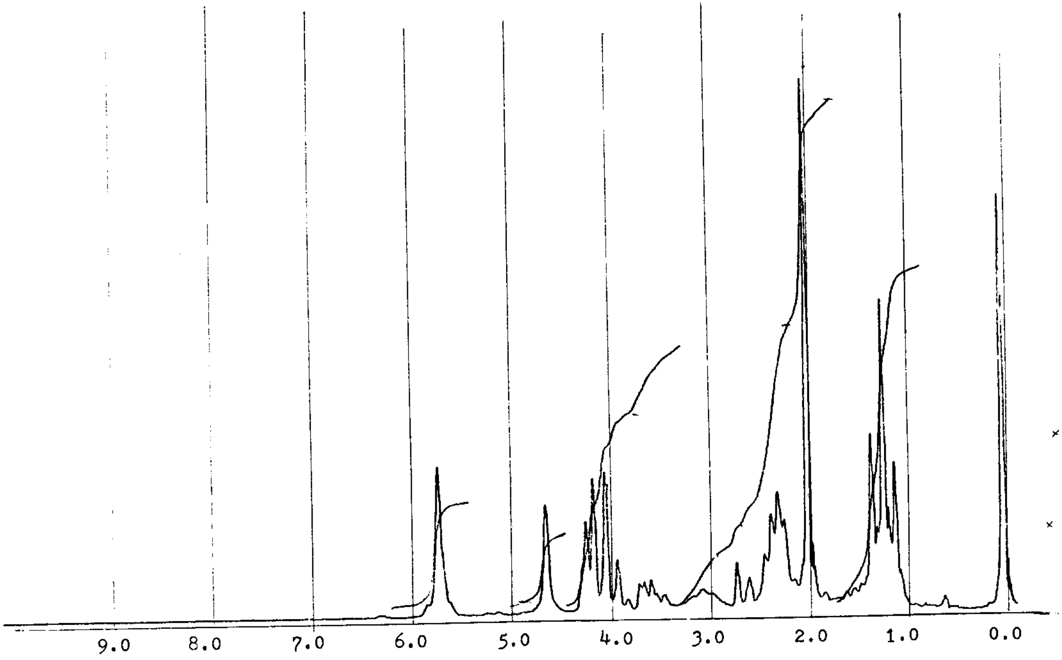
TMS
NEAT

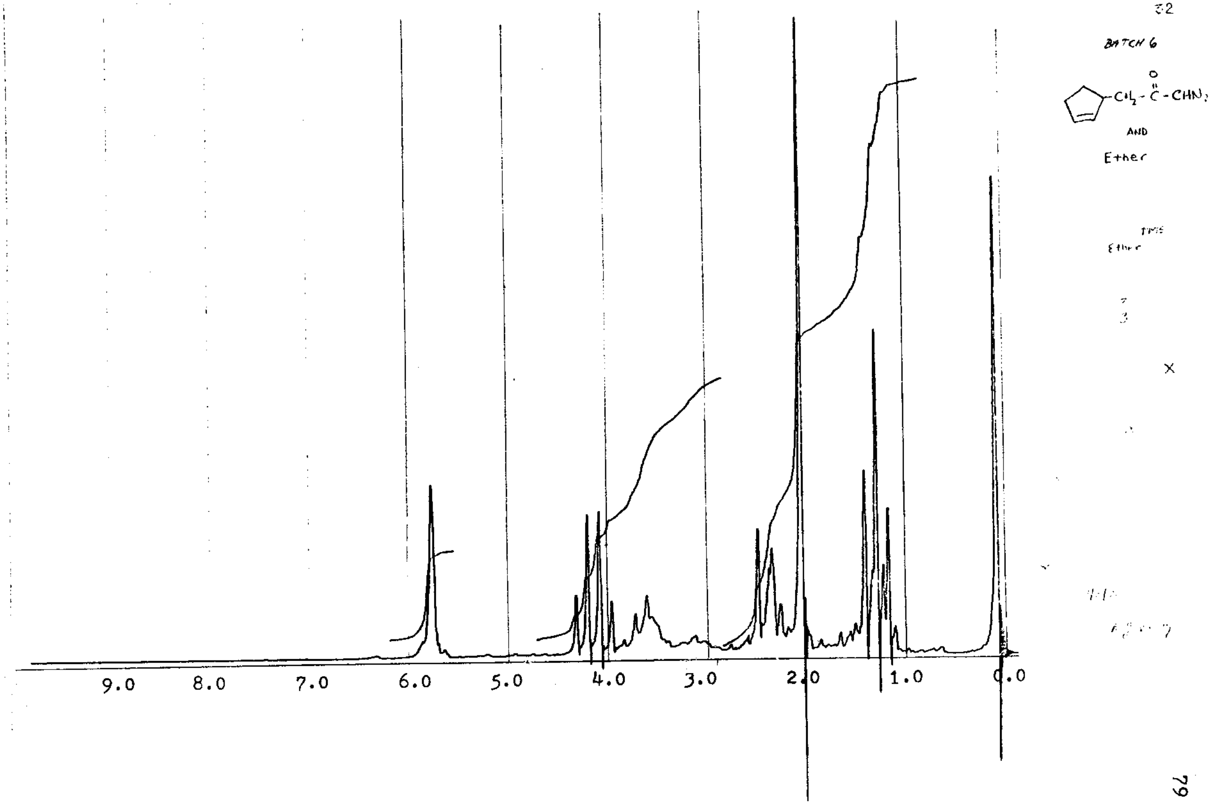
4
4

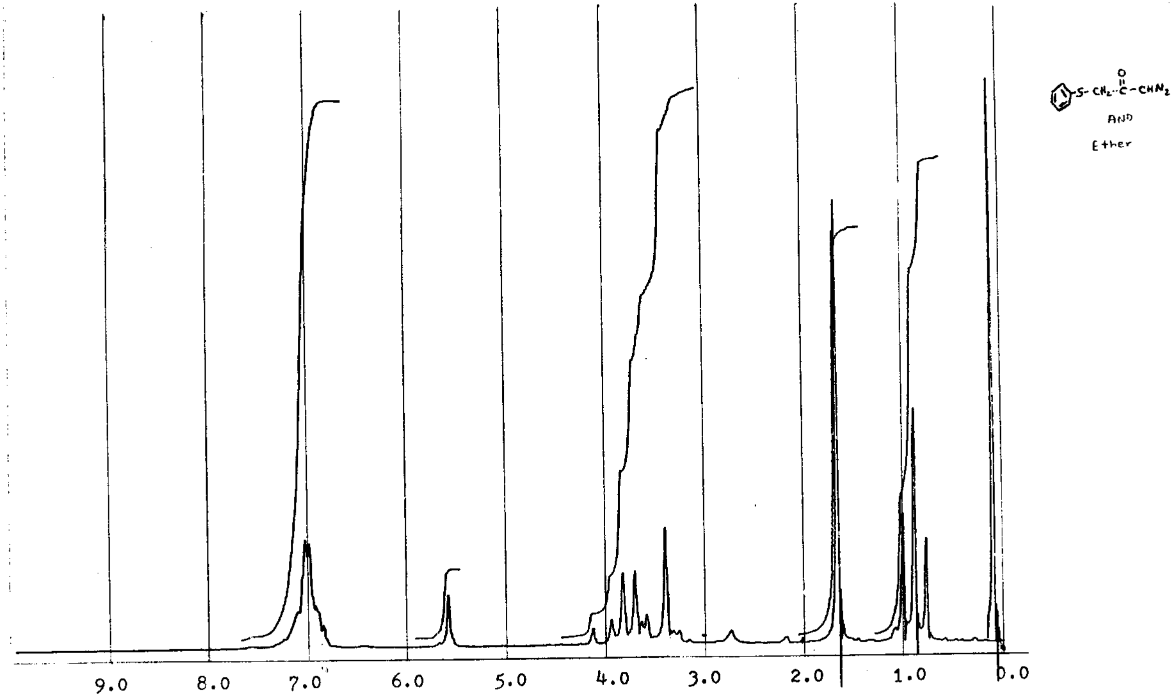
2/2/78

[illegible]

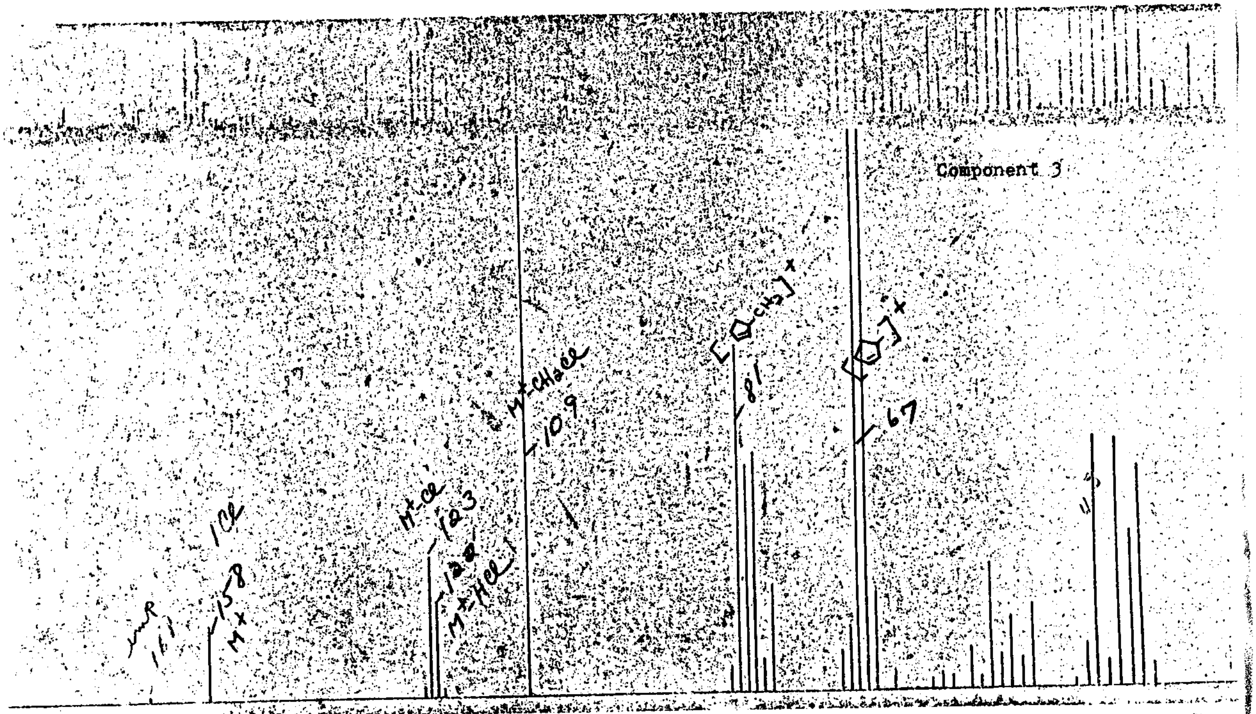
[illegible]

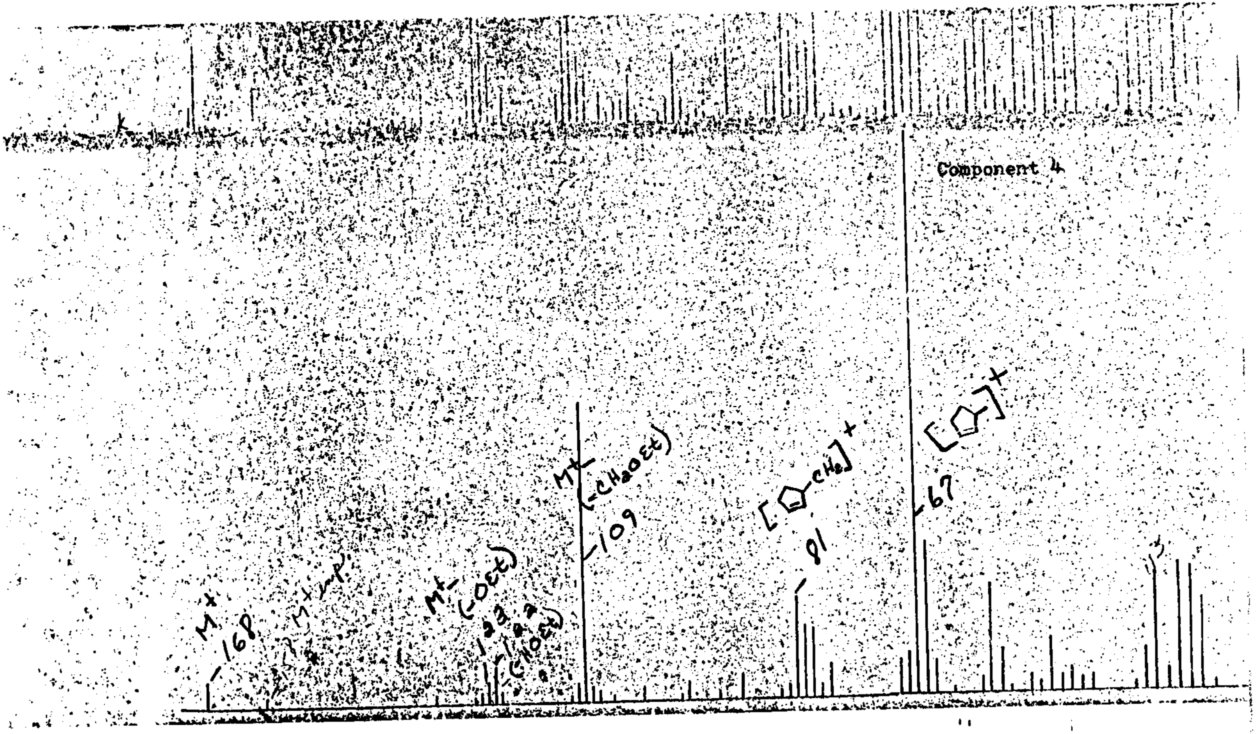



32
BATCH 6
-CH2-C(=O)-CHN2
AND
Ether
TMS
Ether
X
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0


S-CH2-C(=O)-CHN2
AND
Ether
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0

APPENDIX D
Mass Spectra


Component 3
161
158
M+
1Cl
M+-Cl
123
122
M+-HCl
M+-CH2Cl
109
[⬠-CH3]+
81
[⬠]+
67
41



Component 4

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