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THE INITIAL INVESTIGATION OF THE CHEMICAL
REACTIVITY OF OCTAHYDROXYCYCLOBUTANE

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MICHIGAN STATE
UNIVERSITY
FEB 19 1981
THE GRADUATE SCHOOL
OFFICE OF THE

has been accepted towards fulfillment
of the requirements for

Masters degree in Chemistry

Eugene LeGoff
Major professor

Date 18 Feb. 1981

O-7639

THE INITIAL INVESTIGATION OF THE CHEMICAL REACTIVITY OF OCTAHYDROXYCYCLOBUTANE

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Kenneth C. Fey

A THESIS

Submitted to
Michigan State University
in partial fullfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Chemistry

1981

ABSTRACT

THE INITIAL INVESTIGATION OF THE CHEMICAL REACTIVITY OF OCTAHYDROXYCYCLOBUTANE

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The intent of this program was to determine the utility of octahydroxycyclobutane as a C-4 synthon for the synthesis of multicyclic highly conjugated ring systems. These compounds would then be evaluated as organic conductors. A prerequisite for such an organic material is that it be symmetrical and contain a high degree of conjugation. Octahydroxycyclobutane is a prime candidate for such a synthon because it contains abundant functionality as well as the ability thru elimination reactions to form carbon-carbon double bonds resulting in an unsaturated internal C-4 fused ring.

However, evaluation of octahydroxycyclobutane in this role proved disappointing since its reactions with 3-keto structures, 1° alcohols, acid anhydrides, acid chlorides, and o-phenylenediamine were all characterized by poor yields and complex product mixtures. With 2° amines it produced, via ring opening, satisfactory yields of bis(dialkylamino)-2, 3-dihydroxy-2-butenedioic acid salts.

ACKNOWLEDGEMENTS

The author would like to acknowledge the valuable insight, advice, and encouragement of Dr. E. LeGoff during the term of this research project. The author also desires to acknowledge the cooperation of The Dow Corning Corporation for their advance of time and financial as well as moral support.

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The synthesis of fused multicyclic ring structures having a high degree of conjugation for use as organic conductors has been of interest to this lab for some time. One proposal for arriving at such structures was to use octahydroxycyclobutane 1 as a synthon so that a multicyclic compound might be constructed about a central unsaturated cyclobutane ring.

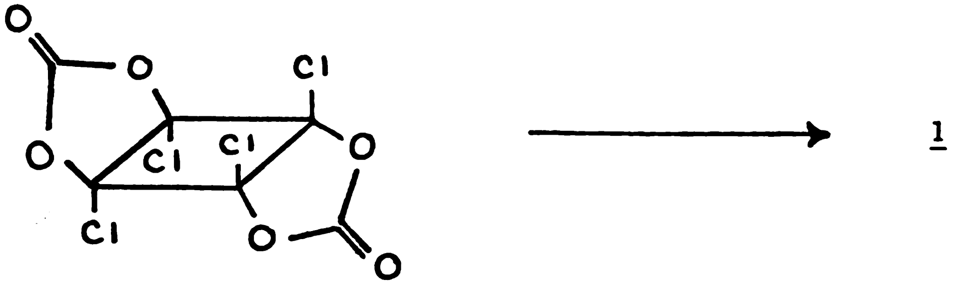
The first reported efficient synthesis of 1 was carried out by West[1], and involved the oxidation of squaric acid (1,2-diketo-3,4-dihydroxy-3-cyclobutene) with either nitric acid or bromine. Infrared (IR) analysis revealed that no carbonyl groups were present indicating a fully hydrated structure rather than one having carbonyl and water groups equilibrated.

Several other papers were published in the next decade which supported West's findings and elaborated further on the structure of 1. Skujins[2] reported from its mass spectrum that mass fragments at m/e 184 and 166 were not observed indicating the ease with which the parent molecule can lose two moles of water. But the fully dehydrated tetrone (m/e = 112) is also absent implying that ring fragmentation occurs prior to complete dehydration. Though West believed 1 decomposed to carbon monoxide at 140°C, Skujins showed that water and carbon dioxide as well are major decomposition products.

Bock[3] studying its crystal structure and Miller[4] its IR and Raman spectra both concluded that the structure of 1 was rigidly planar due to hydrogen bonding of the compound's eight hydroxyl groups. This finding is in contrast to the structure of octachlorocyclobutane as reported by Owen[5]. The latter has a puckered ring structure as one might expect.

C^{13} Nuclear Magnetic Resonance (NMR) analysis of 1 was carried out as part of this study to confirm the earlier IR and Raman spectra which imply the presence of only one carbon species. The spectrum, run in D_2O, revealed a lone sharp signal at $\delta = 87.04$ ppm. By comparison, one would expect to find the $\geq$C-O- structure at $\delta = 73\text{-}85$ ppm.

Only Scharf and Seidler^6 reported any investigation of the chemical reactivity of 1. They isolated it by hydrolysing a photochemical cycloaddition product 2. IR and H'NMR analyses of the hydrolysis product matched the structure for 1 found by West.



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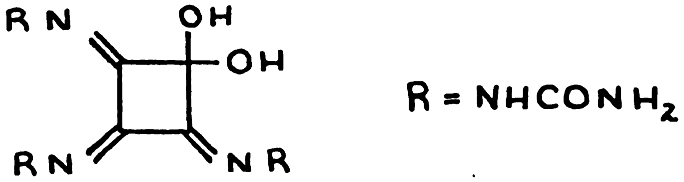
When 1 was reacted with semicarbazide-hydrochloride, compound 3 was isolated. The authors make no suggestion, however, as to the mechanism of this reaction: substitution of hydroxyl followed by dehydration, or dehydration of 1 followed by addition to the resultant carbonyl and finally elimination of water.



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Limited solubility of 1 in most common solvents would make its reaction study quite difficult at times. Dimethylsulfoxide, dimethylformamide, and water would prove to be the only solvents in which 1 could be readily dissolved. Other solvents (i.e. $CHCl_3$, CCl_4, aromatics, ethers, ketones) were incapable of dissolving 1, while materials such as pyridine and alcohols caused significant decomposition to occur within a few hours.

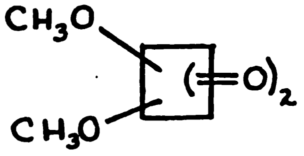
RESULTS AND DISCUSSION

A. Synthesis Of Octahydroxycyclobutane And Other Reactive Intermediates From Squaric Acid

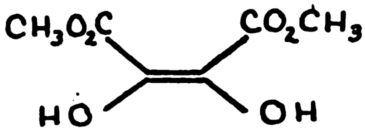
To synthesize 1, West[1] oxidized squaric acid 4 in an aqueous medium with either nitric acid or bromine, 84% or 70% yield respectively. During this study, that synthetic procedure was improved by incorporating acetone into the reaction medium. The increased yield (now >90%) likely is attributable to acetone's ability of rapidly precipitating 1 from the reaction solution as it is formed thus minimizing any oxidative degradation of the product.

Speculation concerning the mechanism for this reaction pointed toward an oxidation of 4 to some intermediate which then was reduced via hydrolysis. Should this be operative, one might expect a methylated adduct of 1 if water is replaced with methanol.

This was attempted using bromine as the oxidant, and a few off-white crystals (mp = 169-171°C) were isolated, 5. Mass spectral data indicated the largest fragment to be m/e = 176. This corresponds to two possible isomers: 5a, 5b.



5a



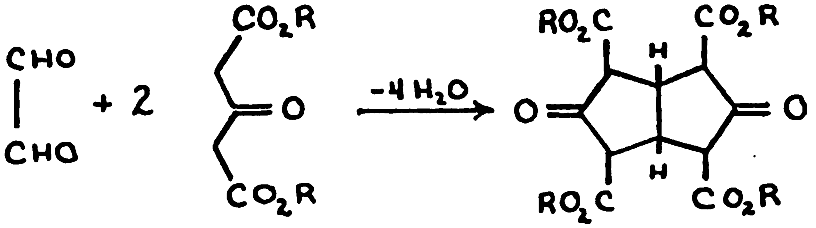
5b

Product 5 was also made via another procedure and this will be discussed in Section C, Results and Discussion. At this time, let it suffice to say that water is by far a more efficient reactant than methanol for converting the oxidized intermediate of 4 to products.

Dimethyl squarate 6 was also used during this study as an intermediate in several reactions. Cohen[7] had synthesized 6 via treatment of 4 with diazomethane, or by reaction of 4's silver salt with methyl iodide. A less hazardous and more rapid procedure was used to generate 6 for this study. Methanol, 4, and an excess of 2,2'-dimethoxypropane were refluxed for 24 hours, concentrated, and the residue recrystallized from boiling ether. The resulting light yellow crystals melted at 55-56°C and the IR analysis was identical to that reported by Cohen.

B. Attempts To Synthesize Multicyclic Structures From Octahydroxycyclobutane And Substrates Containing A 3-Keto Structure

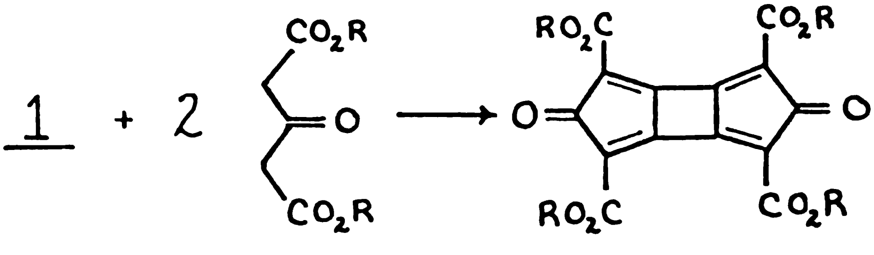
Weiss had reported[8] that dimethyl -3-ketoglutarate and a number of 1,2-dicarbonyl compounds could be reacted at room temperature in aqueous solution to yield fused ring systems (eq. 1).



(eq. 1)

It is likely that the mild acid conditions favor formation of the glutarate's enolate, and that the now slightly anionic methylene carbon attacks the glyoxal carbonyl carbon. Elimination of water leads to the final product.

Our intent of replacing glyoxal with 1 presupposed that these enolates would also attack the election difficient cyclobutane ring carbons as depicted by eq. 2.



(eq. 2)

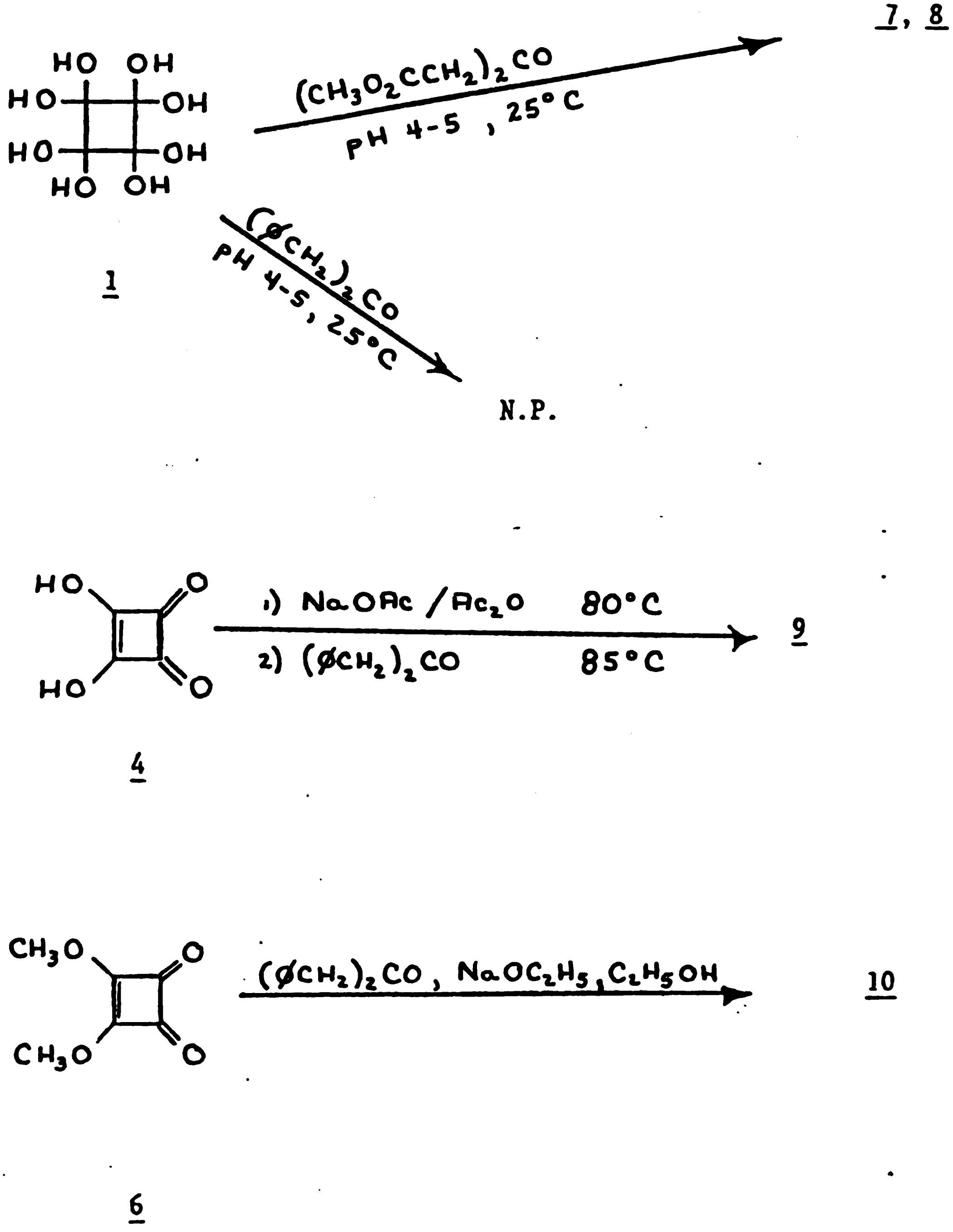


FIGURE 1

ATTEMPTS TO SYNTHESIZE MULTICYCLIC STRUCTURES
USING OCTAHYDROXYCYCLOBUTANE

Figure 1 summarizes these experiments. In each case, the reactions were extremely slow and only a small amount of product could be isolated. Products 7 and 8 were orange-yellow solids which melted at 85-6°C. Their mass spectra indicated the presence of glutarate fragments though it cannot be determined if they result from formation of the desired products or contamination by starting material. The reaction of 1 with 1,3-diphenyl-2-propanone fared worse, as only starting materials could be recovered. But since 1,3-diphenyl-2-propanone is more stable than the glutarates, it was chosen to be used in further attempts to make a multicyclic product.

In one case, the diacetyl derivative of 4 was generated *in situ* by use of sodium acetate/acetic anhydride; the other employed dimethyl squarate 6 in sodium ethoxide/ethanol, an adaptation of the procedure of Schmidt and Reid.[9] Respectively, products 9 and 10 were recovered.

Unfortunately, these reactions also yielded small quantities of products. Tarry reaction mixtures made any straightforward isolation difficult, and consequently those few crystals obtained were only analyzed by elemental and mass spectral methods. Both have similar mass patterns showing diphenylpropanone type fragments while 9 in addition displayed species corresponding to acetyl. Not surprisingly, their elemental analyses revealed no empirical formula which matched any of the observed mass fragmentation patterns.

This concept was as a result abandoned since it was apparent that products obtained would be both quite difficult to purify and in very low yield.

C. Reactions Of Octahydroxycyclobutane With Alcohols, Acid Anhydrides, And Acetals

Assuming 1 behaves as an alcohol, then reaction with other alcohols, acid anhydrides, and acid chlorides should be expected. Consequently,

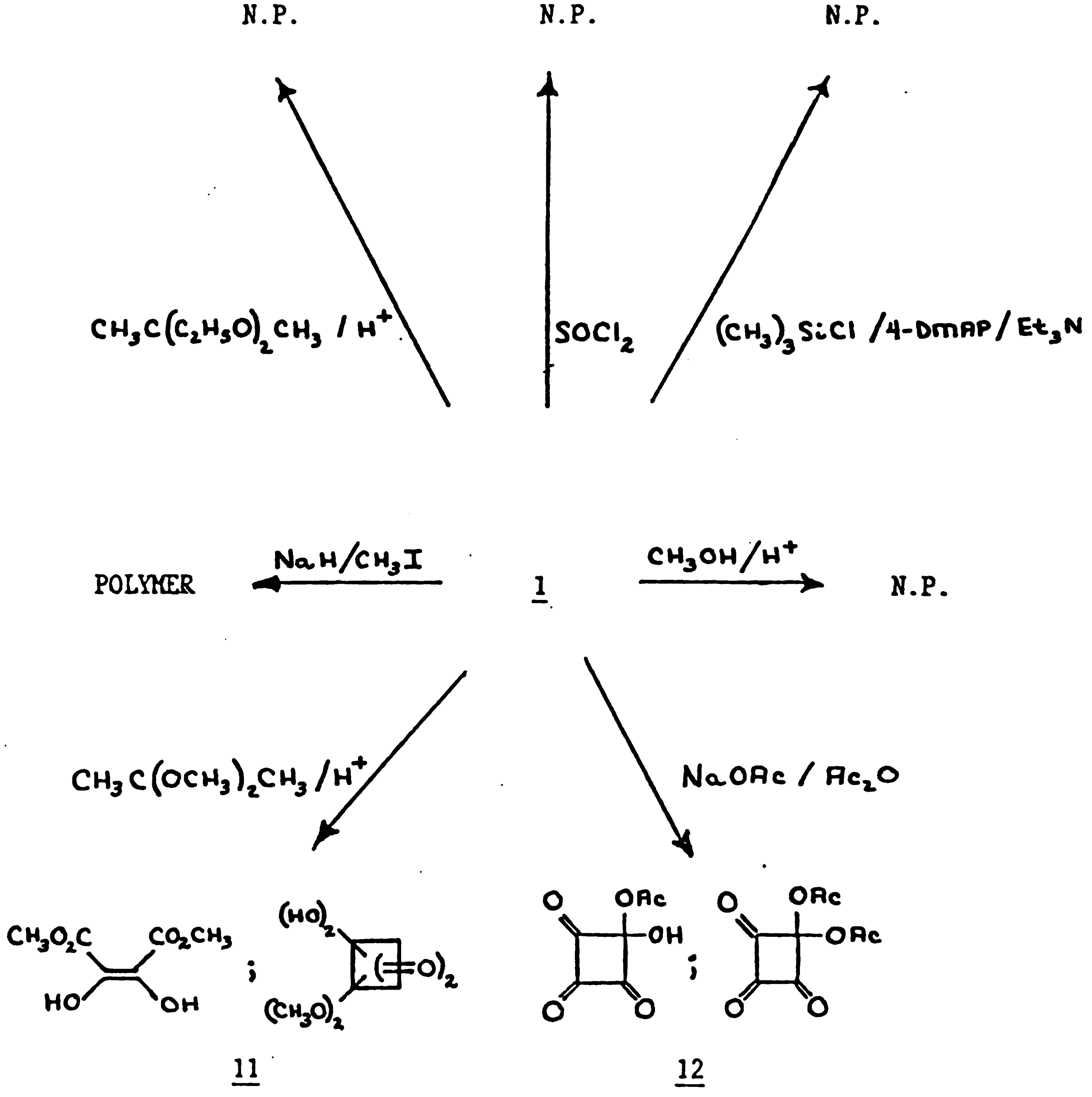


FIGURE 2

REACTION OF OCTAHYDROXYCYCLOBUTANE WITH 1° ALCOHOLS, ACID ANHYDRIDES, AND ACETALS several attempts were made to replace the hydroxyl hydrogens of 1 with methyl or ethyl groups (See Figure 2).

Refluxing 1 in methanol with acid present succeeded in only causing a slow decomposition to occur, while Brown's procedure[10] for methylating glycols (sodium hydride/methyl iodide) yielded what appeared to be an insoluble polymeric substance.

Success was achieved by adapting the procedure used to synthesize 6. Overnight refluxing of 1 and 2,2'-dimethoxypropane in dry methanol yielded a methylated product 11. These fine white crystals melted at 171-4°C and produced the same mass spectral fragmentation pattern as 5 (mp = 169-171°C), the material isolated from the bromine oxidation of 4 in methanol. Elemental analysis of 11 also confirmed that its empirical formula matched that of the proposed structures 5a, 5b.

Despite that only very small amounts of 5 or 11 were isolated, an attempt was made to determine if either 5a or 5b could alone be identified as the correct structure of these products.

Structure 5a could not be found in the literature; however, 5b is known and a wide range of melting points is reported: 165-173°[11], 157-165°[12], 178-180°[13], 174-174°[14]. But only Goodwin[11] reports spectral data for these derivatives of 2,3-dihydroxy-2-butenedioic acid, among them the dimethyl ester (5b). He reports IR bands that are quite like those obtained from a sample of 11 (See Table I).

TABLE I

IR COMPARISON OF 11 WITH 2,3-DIHYDROXY-2-BUTENEDIOIC ACID, DIMETHYL ESTER

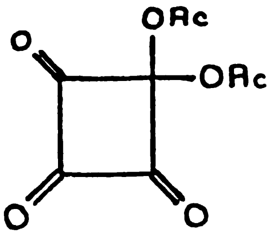
11	2,3-DIHYDROXY-2-BUTENEDIOIC ACID, DIMETHYL ESTER
2.8-3.3w	-
3.39	3.18
6.00s	5.98s
6.90s	6.94s
7.20	7.29
8.00s, br	8.03s
9.80s	9.82s
11.40	11.41
13.00	-
14.60	-

This data suggests that 5b is the correct structure, but it does not completely eliminate 5a. One isomer of 5a is 1,2-diketo-3,3', 4,4'-dihydroxy-dimethoxycyclobutane, and such 1,2-diketo compounds display a sharp band at ~6.0 microns.

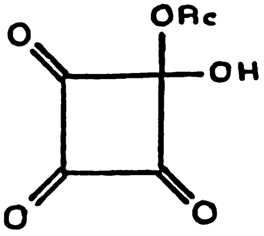
C^{13} NMR could be used to resolve this question since 5a would show (C = O) and (3°) carbon species while 5b would display (C = O) and (C = C) carbons. Unfortunately the yields of both reactions (5 and 11) are so poor that far too little of the product could be isolated for C^{13} analysis.

An attempt was made to make the ethylated derivative of 1 using 2,2'-diethoxypropane in refluxing ethanol. Unfortunately, a very complex product mixture results as well as significant decomposition of 1, and no product could be isolated.

Numerous attempts were made to substitute acetoxy groups into compound 1, but all met with only limited success at best. Reagent combinations such as acetic anhydride/4DMAP (4-dimethylaminopyridine)[15], sodium acetate in acetic acid, trichloroacetic acid/acetic anhydride and sodium acetate in acetic anhydride, were employed. The most successful of these combinations was the last. The yellow oil that resulted could be chromatographed to yield a fraction which when analyzed by mass spectroscopy indicated fragments corresponding to structures 12a-b. Other analyses could not be performed however because the sample was impure and of a very small amount.



12a



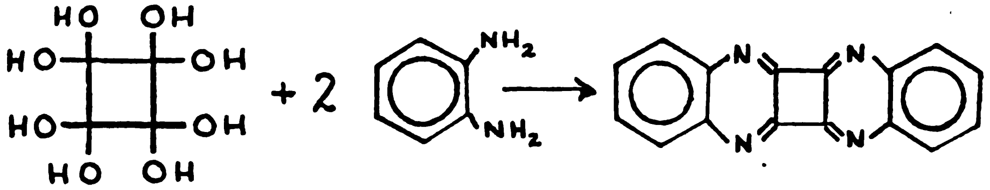
12b

Thionyl chloride was used to attempt chlorination of 1, according to the procedure for generating dichlorosquarate[16]. These reactions easily generated black tars while surprisingly a significant portion of unreacted 1 could be recovered.

Silylation of 1 using Me_3SiCl/4-DMAP/$(Et)_3N$ was also attempted, the 4-DMAP reportedly being very effectively in these applications.[17] However little product was isolated and no unreacted 1 could be recovered leading to the conclusion that decomposition was occuring rapidly.

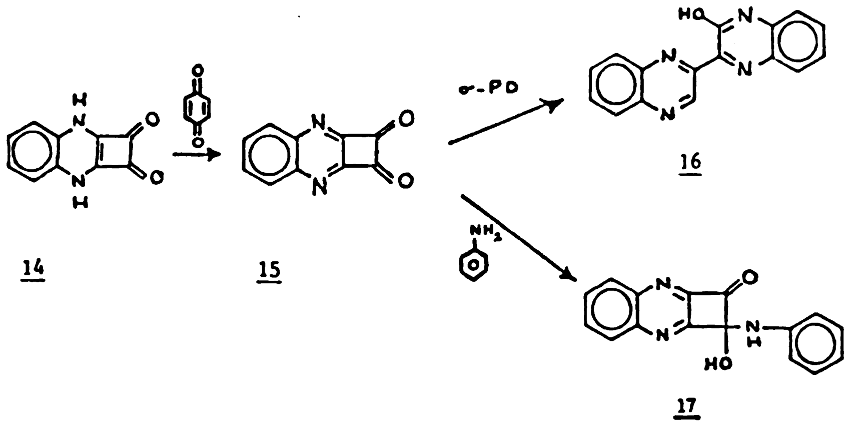
D. Reaction Of Octahydroxycyclobutane With o-Phenylenediamine

One goal of this project was to determine if 1 could be used as a cyclobutane synthon for multicyclic fused ring systems. The principle approach used toward achieving this goal was the reaction of 1 with o-phenylenediamine (eq 3).



1 13 (eq. 3)

Although a synthesis of 13 is not mentioned in the recent literature, a number of analogous reactions using squaric acid 4 and o-phenylenediamine (o-PD) are reported. From 4 and o-PD, Erhardt[18] and Skujins[19] both synthesized 14, from which Erhardt obtained the aromatized adduct 15 by use of benzoquinone/DMF. The reactions of 15 with aniline or a second equivalent of (o-PD) yielded 17 and 16 respectively, the suggestion being that the second equivalent of (o-PD) cannot cyclize with the C-4 ring before the latter is opened. Erhardt also reports a number of cases when water is observed to hydrolyze and open the C-4 ring of 15 presumably by nucleophilic attack at the carbonyl. But attempts to arrive at 13 by reaction of 4 with two equivalents plus an excess of (o-PD) do not appear successful.



Replacement of 4 with 1 was contemplated as a means of synthesizing 13 since initial attack by the amine groups conceivably could occur at a greater number of ring carbons than with 4. This was attempted using two reaction media (Figure 3).

Products from each system form rapidly. A very intense deep red to dark violet color also emerges almost immediately upon mixing of the reactions. Unfortunately, the products obtained are sparingly soluble in most common solvents and as a result purification was difficult.

The 1:1 adducts, 14 or the isomer 18, were found by IR to contain NH (3.23μ) and 1,2-dicarbonyl (5.55-5.65μ) groups, but no hydroxyl was noted. The mass spectral analysis matched that reported by Webb.[19] On the strength that no hydroxyl bonds were found in IR analysis, structure 14 was deemed the correct configuration.

In attempts to produce 13, (o-PD) was reacted with 1 in 2:1 and 3:1 ratios. In the former case, a mass spectrum showed a fragmentation pattern corresponding to the presence of 19 or its isomer 16 which was isolated by Erhardt.[18] An IR analysis indicated NH groups, no OH groups, and was inconclusive on the presence of >C = O species. Since the solubility of this material was quite low, no H'NMR could

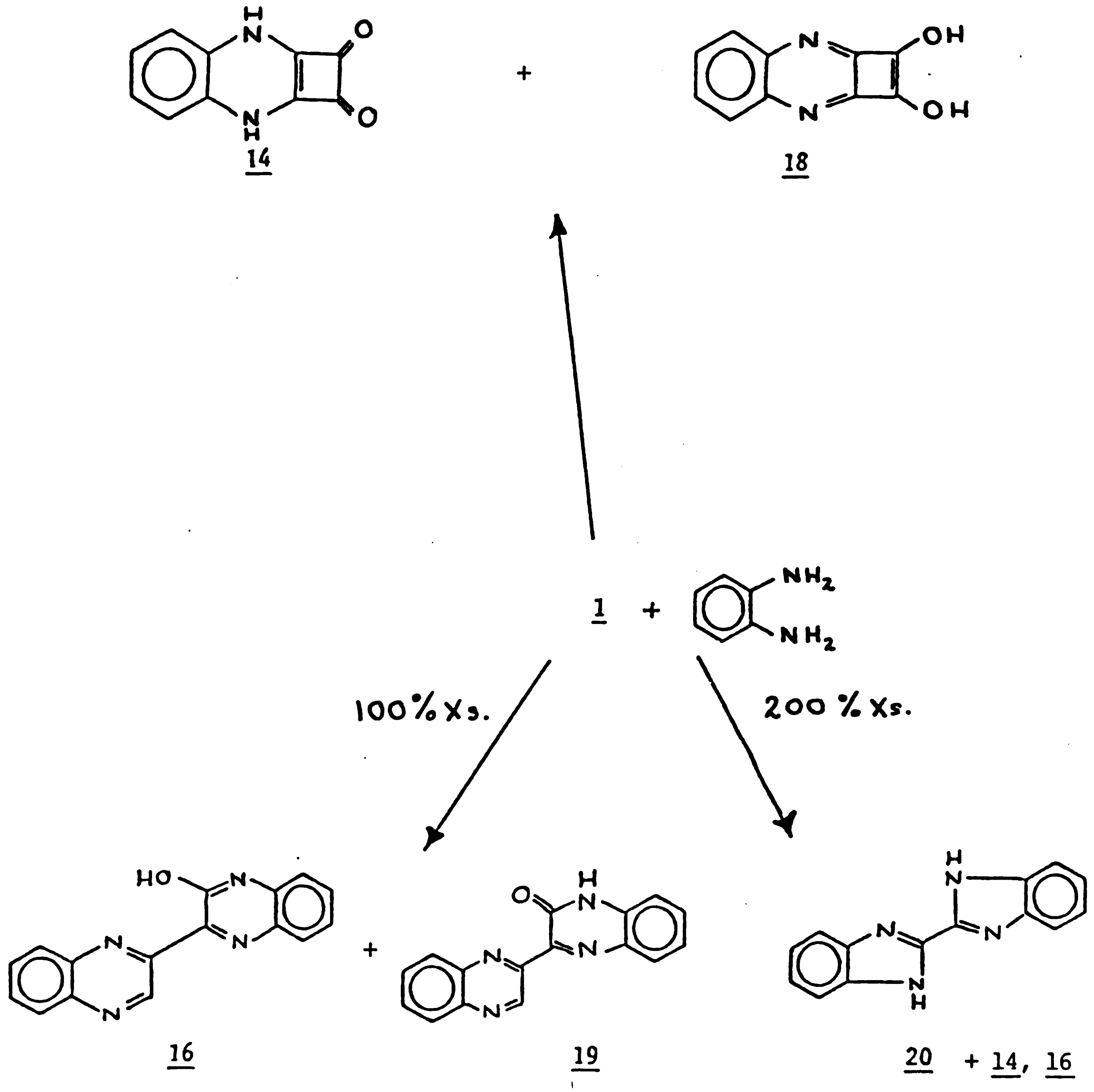
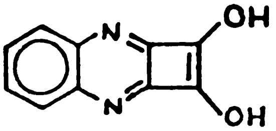
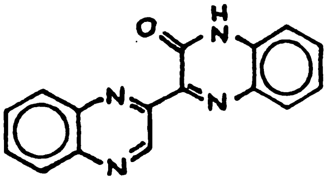


FIGURE 3

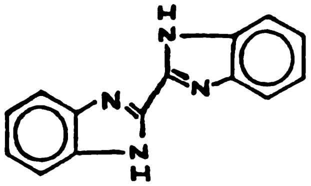
REACTION OF OCTAHYDROXYCYCLOBUTANE WITH o-PHENYLENEDIAMINE be run to aid in resolving the structure. The purity of the sample itself was questioned when elemental analysis revealed a chemical composition not consistent with the other structural data.



18



19



20

The 3:1 adduct also was a victim of its inability to be purified. Mass spectral data suggests that fragments corresponding to 16, 14, and 20 are present, and not surprisingly IR and elemental analyses prove inconclusive.

Two comments should be made. First, the initial substitution of 1 by (o-PD) must also promote dehydration of the remaining adjacent hydroxyl groups since the products formed are identical to those found from the reaction of 4 with (o-PD). Secondly, since yields are significantly higher when 4 is used, one can conclude that 1 is more susceptible to C-4 ring opening processes than is 4 or 15.

E. Reactions Of Octahydroxycyclobutane With 2° Amines

The reaction of 1 with o-phenylenediamine indicated the instability of 1 in a concentrated 1° amine solution. This, in spite of the fact that Scharf[6] had isolated the imine product of 1 and semicaribazide-hydrochloride. Thus it would appear that imine-containing derivatives of 1 can only be synthesized under mild and/or specific reaction conditions.

The decision to investigate reactions of 1 with 2° amines is predicted on the basis that these reagents will not form imine structures, thus hopefully permitting isolation of more stable derivatives of 1. This was found to be an accurate assumption as slow addition of 2° amines to aqueous solutions of 1 at 0°C lead to good yields of stable products (Table II).

TABLE II

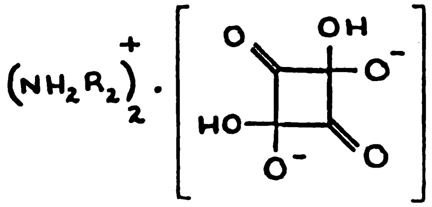
REACTIONS OF 1 WITH 2° AMINES

#	AMINE	YIELD[a]	DECOMPOSITION POINT(°C)
22	Diethyl	43.74	166.5-167.5°
23	Diisopropyl	47.58	193.5-194.5°
24	Dimorpholino	57.74	194°
25	Dicyclohexyl	2.16	201-202°
26[b]	Diethyl	8.75	175-177°

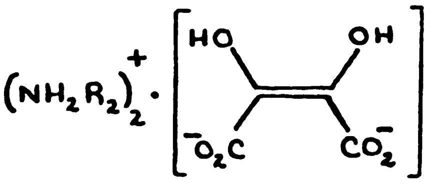
[a] Based on 1, recrystallized product.
[b] 4 used instead of 1.

However, since a saturated, amine-substituted cyclobutane product was anticipated, it was surprising to find that 22, 23, 24, and 25 all possessed a strong IR band at 6.23μ indicating the possibility of the carboxylate ion group. Having noted that the reaction of 1 with o-phenylenediamine resulted in products similar to those obtained from 4 and o-phenylenediamine, the suspicion arose that 1 may have been reduced to a squarate-type intermediate in this reaction as well. As noted in Table II, this hypothesis was disproven when squaric acid and diethylamine were reacted (26). Product 26 is not the same material as 22.

Elemental analyses of 22-25 reveal each product has the same empirical formula: $(C_2H_3O_3NR_2)_n$ where R is the appropriate alkyl group. Structures 27a,b represent those 4-carbon amine salts that correspond to the empirical formula.



27a



27b

But only 27b contains a carboxylate structure, as suggested by the IR, and 27a is likely to be unstable.

C^{13}NMR analysis of 22 and 23 reveal a low intensity pair of signals at δ = 174± 0.05ppm (C = O) and δ = 137 ± 0.05ppm (C = C) as well as the amine carbon signals which are quite strong.[a] If these signals do correspond to (C = O) and (C = C) as represented in 27b, then their low intensity would be expected because no hydrogen is bonded directly or adjacent to these carbons.

Proceeding on the assumption that 27b is the correct structure, a neutralization equivalent was performed on 24. The actual molecular weight of 24 is 322.31g, and the test value obtained was 323.51g. Following this, the free acid was isolated (29) by neutralization using concentrated hydrochloric acid. IR analysis of the product matched the bands reported for 2,3-dihydroxymaleic acid[21] (2.85s, 3.24w, 5.2m, 6.14s, 6.40w, 6.75-6.85s, 8.0-8.4s, 9.6w, 10.6m, 12.8m micron).

A subsequent literature search for related compounds revealed that the trans form of 22 and 23 had been previously reported.[22] Table III *shows* the comparison of reported decomposition points. Comparison of the infrared spectra suggests 22 has the trans form, but the conformation for 23 is not so implied. Yet in either case, this data is not conclusive evidence for the correct conformation.

TABLE III

COMPARISON OF 27b DECOMPOSITION POINTS

		DECOMPOSITION POINTS (°C)	
#	AMINE	OBSERVED	REPORTED
22	Diethyl	166.5-167.5	168-169
23	Diisopropyl	193.5-194.5	183-184

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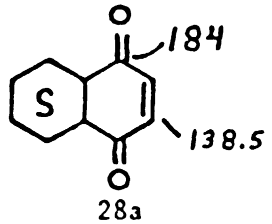
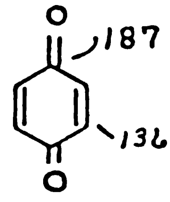
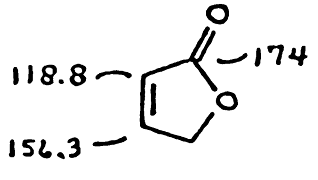
[a] Analogous structures and their C^{13}NMR values taken from ref.[23] are:



28a



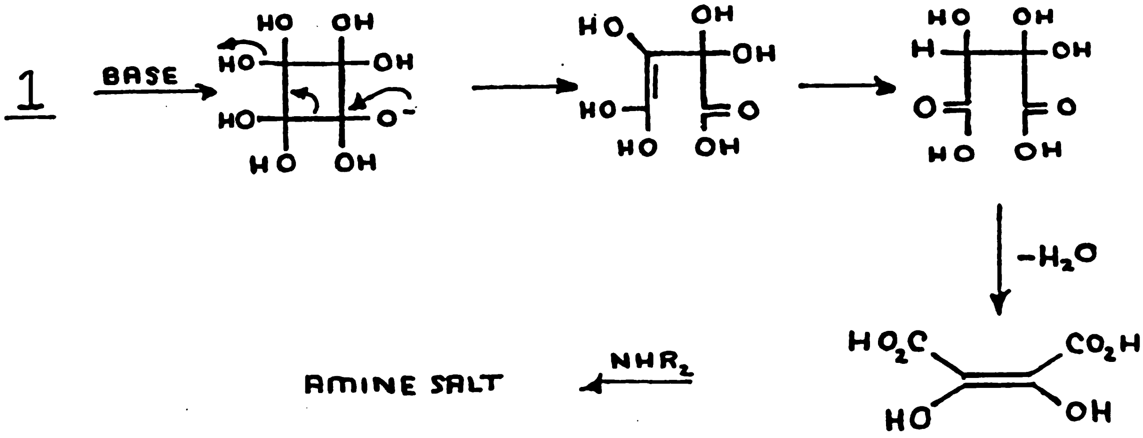
28b



28c

Hartree[24] addressed a similar configuration question for maleic acid methyl esters in 1953. He resolved that the free acid is in the trans form in solution, a form he trapped by using diazomethane to form the corresponding methyl esters. Gupta[25] later confirmed Hartree's conclusions from X-ray studies of the acid's crystalline dihydrate. Since 22-25 are quite closely related to maleic acid, their X-ray analyses should also be capable of satisfactorily verifying their configurations.

Finally, these unexpected products' formation might be explained by the following mechanism. Following an initial loss of one proton, the formation of a carboxylic acid group and ring opening take place. This is accompanied by the loss of a mole of water. A subsequent rearrangement to form the second acid group followed by the elimination of another mole of water yields the free acid.

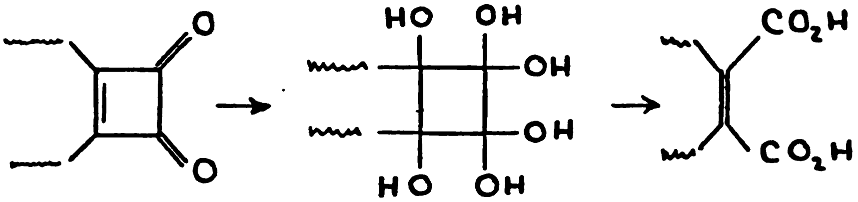


CONCLUSION

The principle goal of this project was to use 1 as a cyclobutane synthon to synthesize fused ring systems. That this goal was not achieved is probably due to 1's unique cage structure of hydrogen bonds, a structure influential enough to render 1 planar and quite stable. This stability, however, is lost upon disruption of the hydrogen bonding configuration. The low yields, high reactivity, and low degree of specificity displayed by 1 are indications of this unique molecular structure.

Generally, many of 1's reaction products are those same materials isolated from reactions of squaric acid, the reduced form of 1. This implies that 1 can easily be reduced to squaric acid-type intermediates.

An unexpected result of this study was the identification of the unique reaction products of 1 and 2° amines. This facile route to aliphatic C-4 unsaturated dicarboxylic acids might be considered in the following sequence for introducing acid groups into cyclobutane rings. Such a sequence would enable the subsequent formation of additional fused rings via the acid groups.



The author would like to see X-ray analysis of the C-4 acid salts to confirm their geometric configurations. Also an effort to improve the yields of reactions 5 and 11 would be in order so that C^{13}NMR analysis could be used to elucidate the structure of these materials.

EXPERIMENTAL

Octahydroxycyclobutane was recrystallized from water-acetone and o-phenylenediamine from methanol prior to being used. All other reagents were used as received. 2,2'-dimethoxypropane was prepared by the procedure of Hured and Pollack.[26] Analytical data was obtained from the following: H'NMR, Varian T-60 spectrometer; C^{13}NMR, Varian CST-20 spectrometer; IR, Perkin-Elmer 237D; mass spectrometer was manufactured by Hitachi. Elemental analysis were determined by the Analytical Laboratory of the Dow Corning Corporation, Midland, MI., 48640. Melt points were run on a Hoover-Thomas apparatus and are uncorrected.

Octahydroxycyclobutane 1

Squaric acid (4, 10g., 87.7mmol) was dissolved in 100ml H_2O-50ml acetone. Bromine added dropwise at 0°C until yellow color persisted. Product spontaneously precipitated from solution during bromine addition after which cooling for 30 minutes in a Dry Ice-acetone bath was maintained. Additional acetone added (100ml) prior to filtration. White crystals (15.2g (94.17% based on 4) mp: 138-139°d). Recrystallized from a minimum of H_2O-100ml acetone, mp: 140°d. IR (Nujol, microns): 3.00s, br; 8.60s; 9.2s; 11.20sh Mass spectrum identical to literature.[1] Calculated for $C_4H_8O_8$: C, 26.09; H, 4.35. Found: C,26.13; H, 4.36.

Dimethyl Squarate 6

Squaric acid (4, 10g, 87.72 mmol) was charged to dry MeOH (100ml) and 2,2'-dimethoxypropane (50ml, Eastman). After 10 hours of refluxing, and every 3 hours afterward, 25ml of condensables were removed using a Dean Stark trap. After 19 hours, the remaining condensables were removed. The resulting residue was dissolved in boiling pet ether (250ml), filtered, then allowed to crystalize. The light yellow crystals obtained were washed with hexane and vacuum dried. (7.91g, 63.5% yield, mp: 55-6°C). IR(KBr, microns): 3.36m, 4.44w, 5.55s, 5.75s, 6.28s, 6.75s, 7.05s, 7.30s, 8.15m, 8.70m, 9.20s, 9.65s, 10.80s, 12.15s.

Product 5, Reaction of 4 with Bromine in Methanol

Squaric acid (4, 0.5g, 4.38 mmol) was dissolved at 35°C in dry MeOH (50ml) and then bromine was added until a faint yellow color persisted. Removal of volatiles yield a beige-colored paste which upon suspension in cold MeOH yielded a small amount of white crystals (mp: 169-171°). Chemical analysis was limited to a mass spectrum, largest fragment: m/e = 176.

Product 9, Reaction of 4 with 1,3-Diphenyl-2-Propanone

Squaric acid (4, 2g, 17.54mmol) was mixed at 80°C with acetic anhydride (50ml) and a small amount of sodium acetate. The resulting squaric diacetate was combined in situ with 1,3-diphenyl-2-propanone (2.46g, 11.75 mmol). After 36 hours at 80-85°C, the remaining acetic anhydride was removed using a rotary evaporator. The residue was taken up in ether and a small amount of hexane; the unreacted squarates being insoluble were filtered. The ether solution was washed twice with H_2O (50ml), then concentrated to a thick dark oil. Redissolution in cold ether (10ml)-hexane (2ml) yielded a few milligrams of an orange powder (mp: 180-6°C). Mass spectral analysis showed fragments of diphenylpropanone; however, little else could be deduced. Elemental analysis: Found: C, 83.3; H, 6.80.

Product 7, Reaction of 1 with Dimethyl-3-Ketoglutarate

Octahydroxycyclobutane (1, 1g, 5.43 mmol) was dissolved in H_2O(75ml), then dimethyl-3-ketoglutarate (0.95g, 5.43 mmol) was added, and the pH adjusted to 4-5 with dilute potassium carbonate. Mixture stirred at 25°C for 96 hours during which time it turned a deep yellow. Removal of the water resulted in 0.8g of an orange paste which was taken up in H_2O (50ml) and extracted with several portions (50ml) of $CHCl_3$ to remove unreacted glutarate (0.35g removed). The aqueous extract was then saturated with salt, and bit of acetone added. Orange crystals isolated (0.10g, mp: 85-6°d). IR (Nujol, microns): 2.8-3.2w, br; 5.70s; 5.88s; 6.10s; 6.35s; 7.8-8.8w, br. Mass spectral analysis shows fragments corresponding to decomposition of 1 and glutarate. Elemental analysis: Found: C, 24.5; H, 2.60.

Product 8, Same Reaction as Product 7 but with Different Isolation Procedure

The orange paste was taken up in MeOH, unreacted 1 remained insoluble and was filtered off. The MeOH was then removed and the yellow solid was extracted with equal volumes of $CHCl_3/H_2O$, the former removing glutarate impurities. The aqueous portion was then evaporated and the residue taken up in acetone from which 0.4g of yellow crystals were recovered (mp = 86-7°C). Mass spectrum shows m/e = 198 fragment which corresponds to the mono-methyl derivative of 1; the remaining fragments are identical to those found for product 8. Elemental analysis: Found: C, 30.2; H, 4.0.

Product 12, Reaction of 1 with Acetic Anhydride/Sodium Acetate

Octahydroxycyclobutane (1, 0.58g, 3.15mmol) was mixed with acetic anhydride (50ml) and a catalytic amount of sodium acetate, brought to 50°C, and let stir for 24 hours. No reaction appeared to occur, so temperature was raised to 80°C, and let stir for 9 hours after which the remaining acetic anhydride was removed. The resulting dark, thick oil was chromatographed on silica gel, 60 mesh (½" x 6" columns). A 2/1 v/v hexane/ chloroform solvent eluted a fraction of product having a strong acetic anhydride odor. Upon setting for several days this solution yielded a few milligrams of light yellow crystals. Mass spectral analysis shows fragments at m/e = 172 and 214, corresponding to (triketo-hydroxy-acetoxycyclobutane) and (triketo-diacetoxycyclobutane) respectively.

Product 11, Reaction of 1 with 2,2'-Dimethoxypropane

Octahydroxycyclobutane (1, 1.55g, 8.42 mmol) was refluxed with 2,2'-dimethoxypropane (20ml, 192 mmol, Eastman), dry MeOH (50ml), and a catalytic amount of p-toluenesulfonic acid. After 12 hours 10ml of volatiles were removed via a Dean Stark trap, and an additional 10ml were removed every 3 hours afterward. When 24 hours of reflux had been completed, all remaining volatiles were removed. The residue was taken up in a minimum of acetone with gentle warming; cooling yielded 0.08g of fine white crystals (0.05% yield, mp: 171-173.5°). IR (KBr, microns): 3.08w; 3.18w; 3.40sh; 6.00s; 6.89s; 7.22s; 8.00; 9.80sh; 11.48sh; 13.00sh; 14.50s. NMR ($DMSO_6$): $\delta = 3.60$ (s, 1.23, OCH_3), 3.75(s, 1.00, OCH_3). Mass spectrum: m/e = 176 which corresponds to diketo-dihydroxy-dimethoxycyclobutane or dimethyl-2,3-dihydroxymaleate. Elemental analysis: Calculated for $C_6H_8O_6$: C, 40.91; H, 4.55. Found: C, 40.83; H, 4.72.

3,8-Dihydro-1,2-Dioxo-Cyclobuta[b] Quinoxaline 14

Procedure (a): Octahydroxycyclobutane (1, 1.43g, 7.77 mmol) was dissolved in H_2O (10ml) while o-phenylenediamine (0.84g, 7.77 mmol)was dissolved in DMF (2.5ml) - H_2O (2.5ml). With agitation at 25°C, the diamine solution was quickly added to 1. Immediately, a dark red solution emerged and precipitation of products began. The temperature was raised to 90°C, and then after 2 hours, it was cooled and the products filtered off. The fine black crystals were sparingly soluble in most organic solvents, and their dilute solutions in water or acetone yielded intense red/orange color. Purification was carried out by refluxing in methylene chloride/ methanol (1/1). Impurities were dissolved, and the products filtered off: reddish brown powder (mp >300°, 15.22% yield). IR (Nujol, microns): 3.25w; 5.57-5.60sh; 6.05s; 6.20s; 6.40s; 13.0w; 13.75w. Mass spectrum corresponds to that reported by Webb.[19] Elemental analysis: Calculated for $C_{10}H_6N_2O_2$: C, 64.52; H, 3.23; N, 15.05. Found: C, 64.20; H, 3.38; N, 15.30.

Procedure (b): Octahydroxycyclobutane (1, 1.0g, 5.43 mmol) was dissolved in 30ml 2N H_2SO_4; o-phenylenediamine (0.59g, 5.43 mmol) was dissolved in 30ml of warm 2N H_2SO_4. Upon mixing at 25°C, a dark red solution formed. Then more 2N H_2SO_4(50ml) was added and the temperature raised to 90°C for 5 minutes. Finally the solution was cooled at 0°C for 8 hours. A dark green solid was first gently filtered and taken up in 150°C 1,2,4-trichlorobenzene to dissolve contaminants. The filtered powder was orange in color (0.12g, 11.88% yield, mp >300°). IR and mass spectrum were identical to those obtained for powder made by procedure (a). Elemental analysis: Calculated for $C_{10}H_6N_2O_2$: C, 64.52; H, 3.25; N, 15.06. Found: C, 64.6; H, 3.38; N, 14.70.

Product 19, Reaction of 1 with 100% Excess of o-phenylenediamine

Procedure (a) used, see compound 14: (1, 1.0g, 5.43 mmol) and o-phenylenediamine (1.17g, 10.82 mmol). The solids filtered from the reaction solution were purified by dissolving contaminants in 200ml of refluxing acetone. A sparingly solution red-brown powder was isolated (0.25g, mp: 198°d). IR (Nujol, microns): 3.17m; 3.38m; 5.60w; 6.05s; 6.22 db, m; 6.40m; 7.70w; 7.85w; 9.67w; 12.75w; 14.10m. NMR($DMSO_6$): δ = 9.67(labile), 6.48 (complex, aromatic). Mass spectrum: m/e = 274, 246 (largest fragments).

Product 20, Reaction of 1 with a 200% Excess of o-phenylenediamine

Procedure (a), per compound 14: o-phenylenediamine (4.0g, 37.0 mmol) and (1, 2.26g, 12.33 mmol). The red-brown solids isolated were further purified by dissolving the contaminants in refluxing ethyl acetate. The residues were filtered and dried yielding a brown powder (0.42g). IR (Nujol, microns): 2.80w; 3.10s; 3.15m; 6.00sh; 6.20-6.25m; 6.43m; 6.57m; 7.60m; 7.80m; 9.55m; 13.60m. Mass spectrum: parent fragment m/e = 234.

General Procedure for Preparing Bis(dialkylamino)-2,3-Dihydroxy-2-Butenedioic Acid Salts

Octahydroxycyclobutane (1, 1.0g, 5.43 mmol) was dissolved in water (5ml), and cooled to 0°C. With stirring over a 5 minute period, the secondary amine was added dropwise. While product precipitated from the solution after several minutes, the reaction solution was kept at 0°C for 1.0 hour. Then 25ml of acetone was added, and the solids filtered off. Purification consisted of dissolving the crude solids in H_2O (20ml) - acetone (100ml) followed by the further addition of acetone (100ml) to precipitate the product.

(a) Bis(morpholino)-2,3-Dihydroxy-2-Butenedioic Acid Salt 24

Morpholine (Eastman, 3.50g, 40.11 mmol). White crystals (0.60g, mp: 196.5-197.5°d). IR(KBr, microns): 3.1-4.5s, br; 6.2sh; 6.75sh; 6.90sh; 7.4-7.6s; 8.15sh; 8.50sh; 9.10sh; 9.55-9.65s; 10.40m; 10.80m; 11.50s; 12.25; 13.1sh. NMR ($CF_3C(OH)_2CF_3 \cdot 1\frac{1}{2}H_2O$): $\delta = 3.38$(qt, CH_2N,1.00), 4.00(qt, CH_2O, 1.00). Mass spectrum: parent m/e = 148(low intensity) plus morpholine fragmentation pattern. Elemental analysis: Calculated for $C_{12}H_{22}N_2O_8$: C, 44.72; H, 6.83; N, 8.70. Found: C, 44.80; H, 6.92; N, 8.45.

(b) Bis(diethylamino)-2,3-Dihydroxy-2-Butenedioic Acid Salt 22

Diethylamine (Eastman, 3.49g, 47.87 mmol). White crystals (0.70g, mp: 166.5-167.5°C d). IR(KBr, microns): 0.7-3.2s, br; 3.4-3.6s; 6.10s; 7.10s; 7.55s; 8.55m; 9.8w; 10.45w; 11.75m; 12.5m; 13.5s. NMR($CF_3C(OH)_2CF_3 \cdot 1\frac{1}{2}H_2O$): $\delta = 3.18$(db, 0.67, NCH_2), 1.39(t', 1.00, CH_3). C^{13}NMR(D_2O): $\delta = 174(C = O)$, $137.5(C = C)$, $48.3(CH_2)$, $19.4\ (CH_3)$. Mass spectrum: parent m/e = 148 (low intensity) plus diethylamine fragmentation pattern. Elemental analysis: Calculated for $C_{12}H_{26}N_2O_6$: C, 48.98; H, 8.84; N, 9.52. Found: C, 48.90; H, 8.80; N, 9.41.

(c)Bis(dicyclohexyl)-2,3-Dihydroxy-2-Butenedioic Acid Salt 25

Dicyclohexylamine (Eastman, 8.65g, 47.78 mmol). Off-white crystals (0.02g, mp: 207-207.5°d). IR(KBr, microns): 3.2-3.45br,s; 6.28s; 6.59m; 6.90sh; 7.40br,s; 8.60s; 9.40s; 10.5w; 11.5s; 13.50s. Mass spectrum: dicyclohexylamine fragmentation pattern. NMR ($CF_3C(OH)_2CF_3 \cdot 1\frac{1}{2}H_2O$): $\delta = 2.20-1.0$, complex. Elemental analysis: Calculated for $C_{28}H_{50}N_2O_6$: C, 65.88; H, 9.80; N, 5.49. Found: C, 62.70; H, 9.36; N, 5.39.

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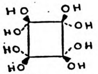
APPENDICES

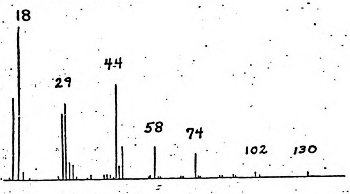
APPENDIX FOR SECTION A

SYNTHESIS OF OCTAHYDROXYCYCLOBUTANE AND OTHER REACTIVE INTERMEDIATES FROM SQUARIC ACID

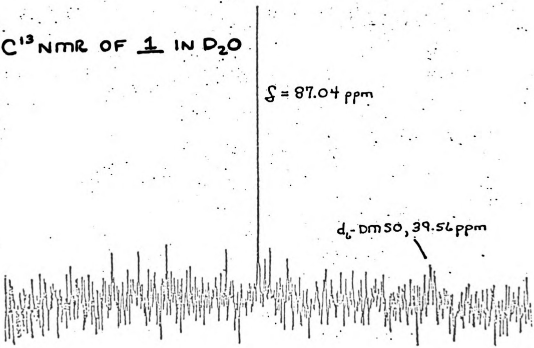
1



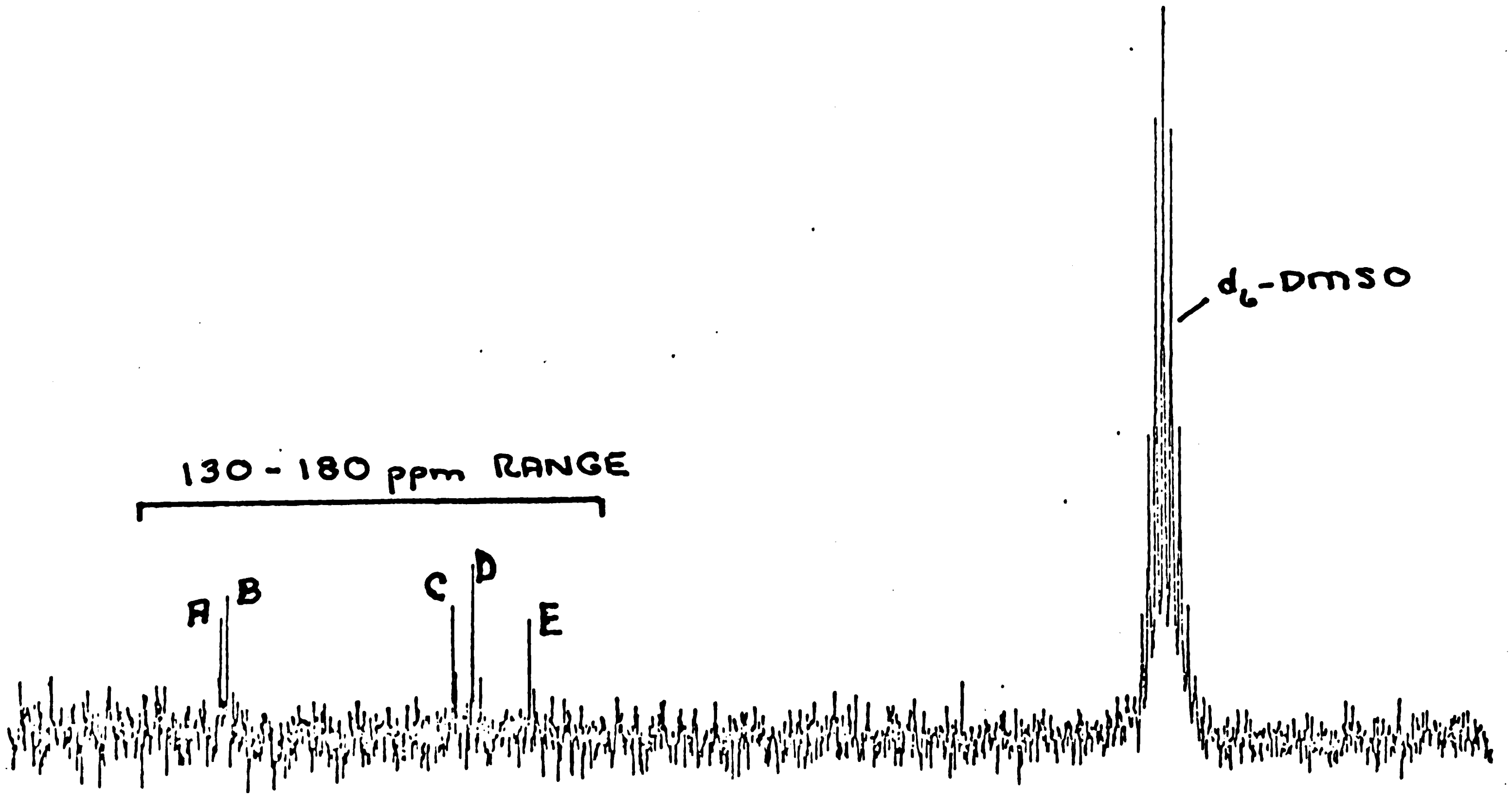
MASS SPECTRUM



C^{13} NMR OF 1 IN D_2O



C^{13} NMR OF <u>1</u> IN d_6-DMSO



Expected	Found
900 (OH)	900
1080 (C-O)	1090
1160 (C-O)	1160
1300 (OH)	–
3250 (OH)	3350

PURITY

PHASE Solid /(mull) NUJOL

CONCENTRATION –

THICKNESS –

DATE 12-8-78

OPERATOR K. FEY

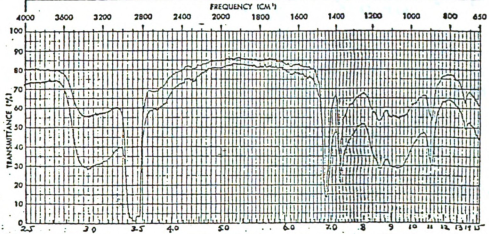
MODEL 700

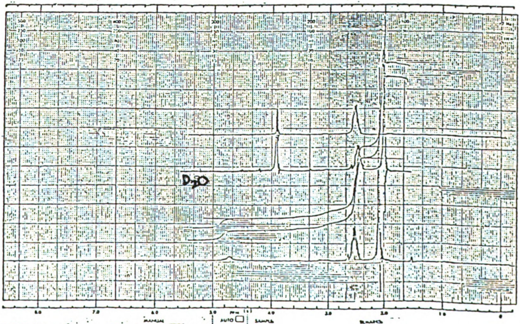
SPECTRUM NO. 1

SAMPLE 1

SAMPLE 2

SAMPLE OCTA (OH) CYCLOBUTANE SPECTRUM NO.





MANUAL

SWEEP OFFSET (Hz) 0

SPECTRUM AMPLITUDE 2.5

INTEGRAL AMPLITUDE 4.0

SPINNING RATE (RPS) 32

SWEEP TIME (SEC)

SWEEP WIDTH (Hz)

FILTER

RF POWER LEVEL 0.05

AUTO ☐

(250)

(500)

(1)

(.05)

SAMPLE

REMARKS

SOLVENT d_6-DMSO

No. VN 1003 (S-60T)

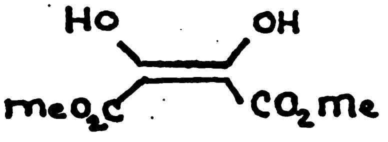
DATE 1-9-79

OPERATOR K. FEY

60 MHz NMR SPECTRUM NO. 1

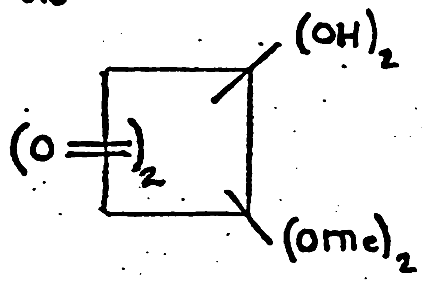
MASS SPECTRUM

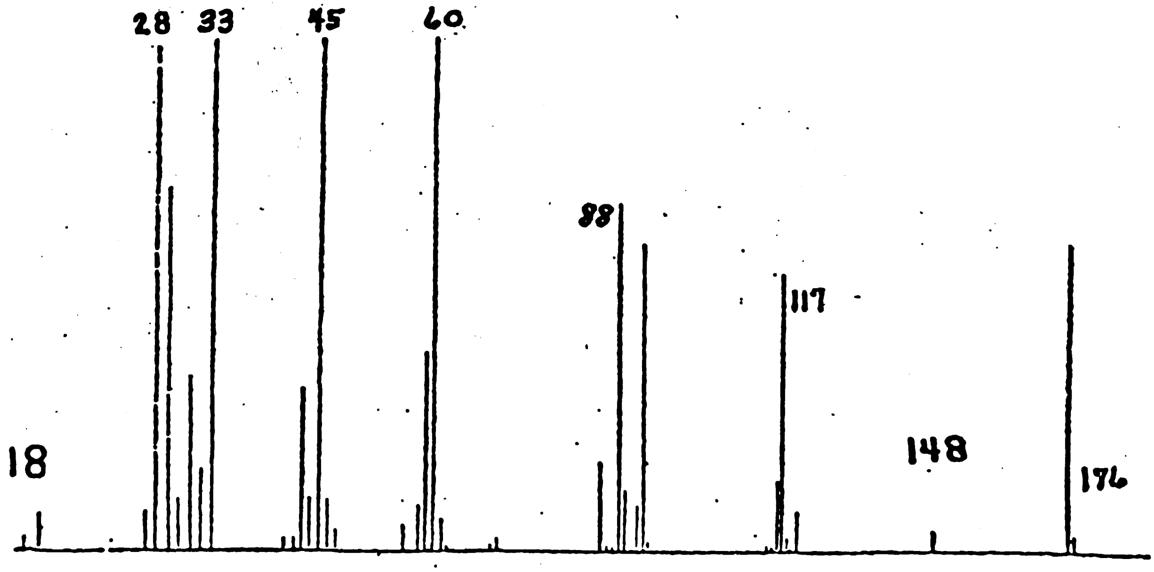
PRODUCT 5 :

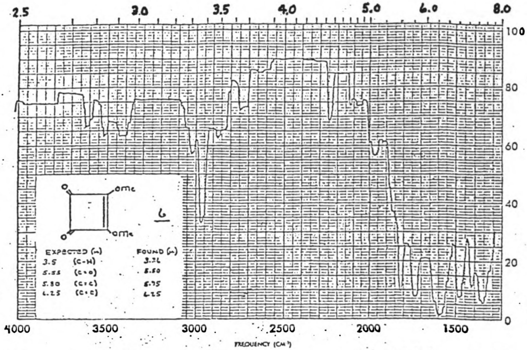


(CIS, TRANS)

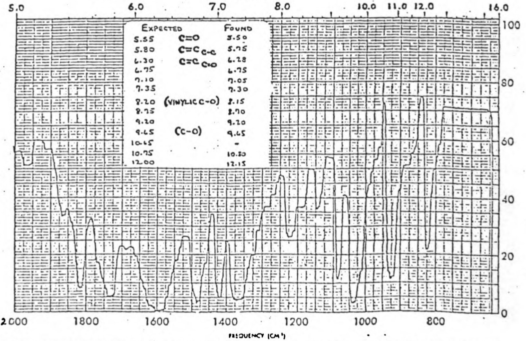
OR







EXPECTED (μ)		FOUND (μ)
3.5	(C-H)	3.36
5.55	(C=O)	5.50
5.80	(C=C)	5.75
6.25	(C=C)	6.25

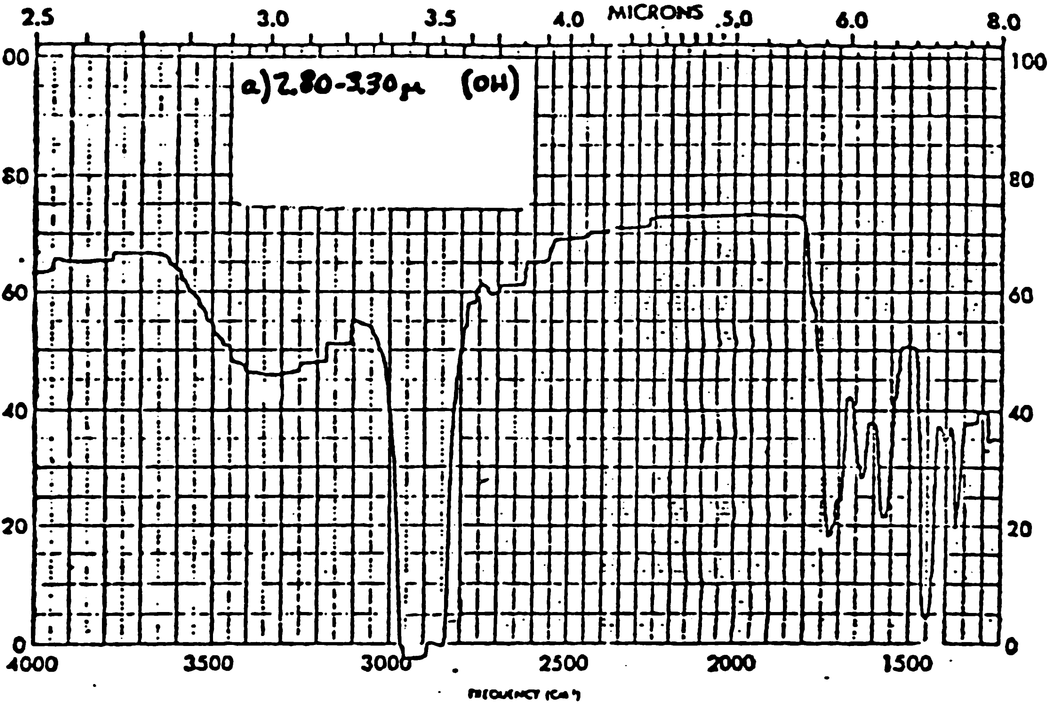


EXPECTED		FOUND
5.55	C=O	5.50
5.80	$C{=}C_{C-C}$	5.75
6.30	$C{=}C_{C=O}$	6.28
6.75		6.75
7.10		7.05
7.35		7.30
8.20	(VINYLIC C-O)	8.15
8.75		8.70
9.20		9.20
9.65	(C-O)	9.65
10.65		-
10.75		10.80
12.00		12.15

SAMPLE DIMETHYL SQUARATE
COMPOUND 6
ORIGIN —
SOLVENT KBR
CURVE NO
CONC —
CELL PATH —
REFERENCE —
SCAN SPEED SLOW
SLIT 6
OPERATOR KF
DATE 2-26-79
REMARKS

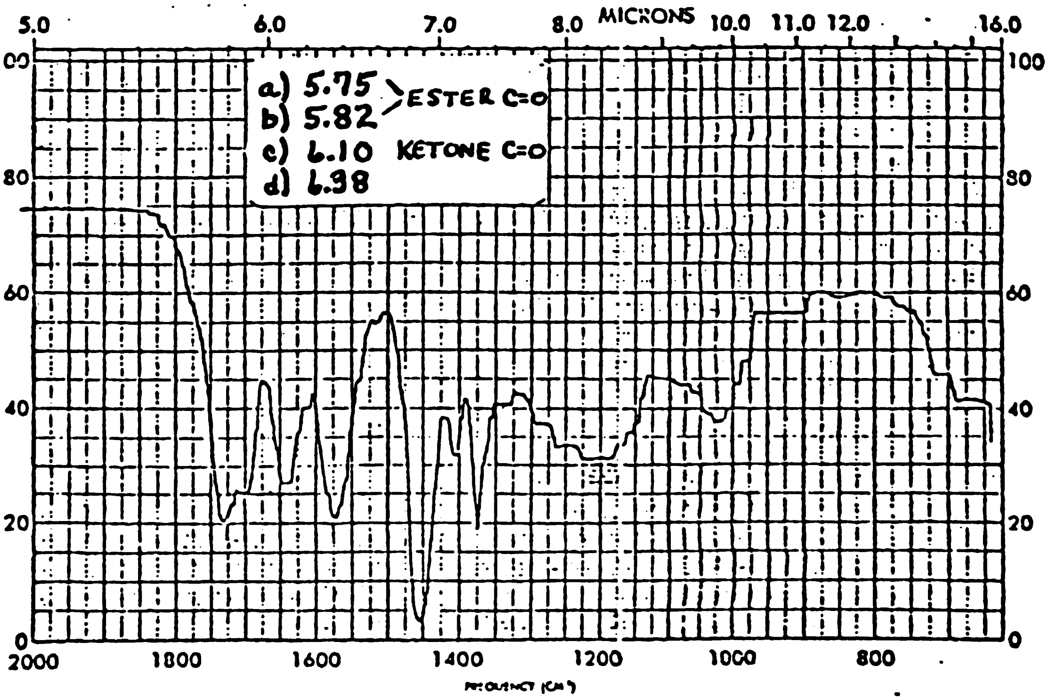
APPENDIX FOR SECTION B

ATTEMPTS TO SYNTHESIZE MULTICYCLIC RING COMPOUNDS FROM OCTAHYDROXYCYCLOBUTANE AND SUBSTRATES CONTAINING A 3-KETO STRUCTURE



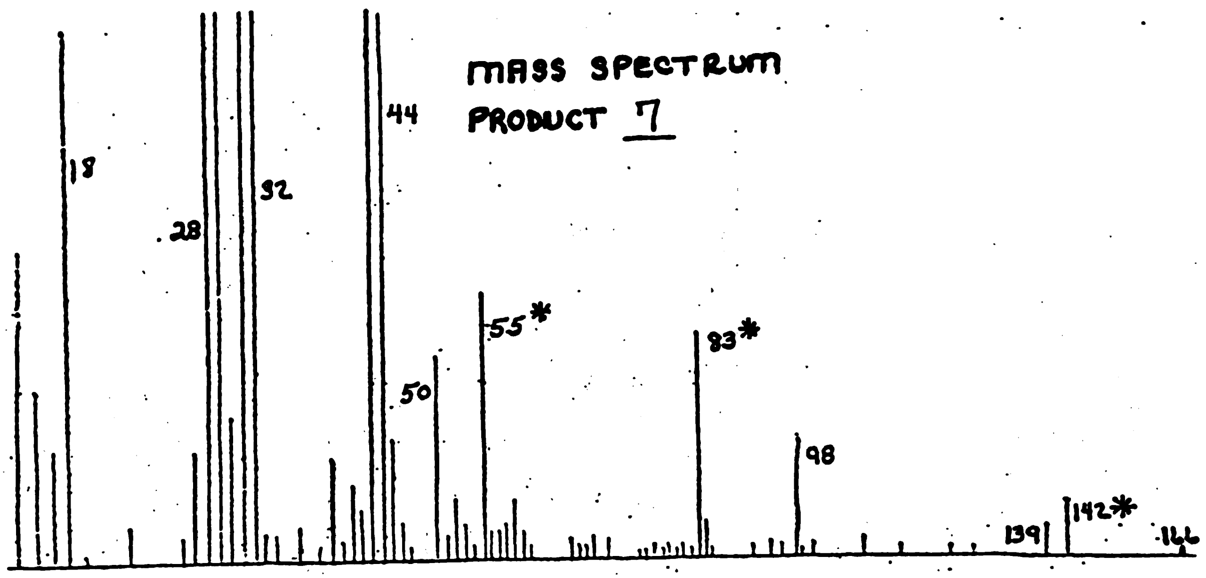
a) 2.80-3.30μ (OH)

SAMPLE PRODUCT 7	CURVE NO.	SCAN SPEED SLOW	OPERATOR KF.
	CONC.	[illegible] 6	DATE 2-1-79
ORIGIN	CELL PATH	REMARKS	
SOLVENT	REFERENCE		



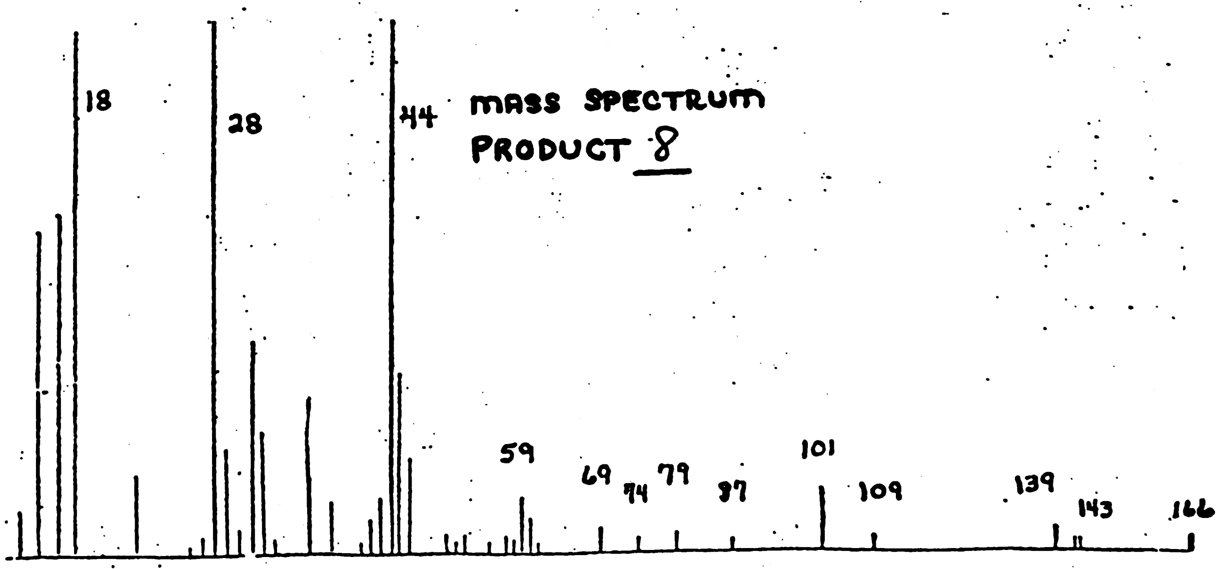
a) 5.75 } ESTER C=O
b) 5.82
c) 6.10 KETONE C=O
d) 6.38

SAMPLE PRODUCT 7	CURVE NO	SCAN SPEED SLOW	OPERATOR KF
	CONC	[illegible] 6	DATE 2-1-79
ORIGIN	CELL PATH	REMARKS	
SOLVENT NUJOL	REFERENCE		



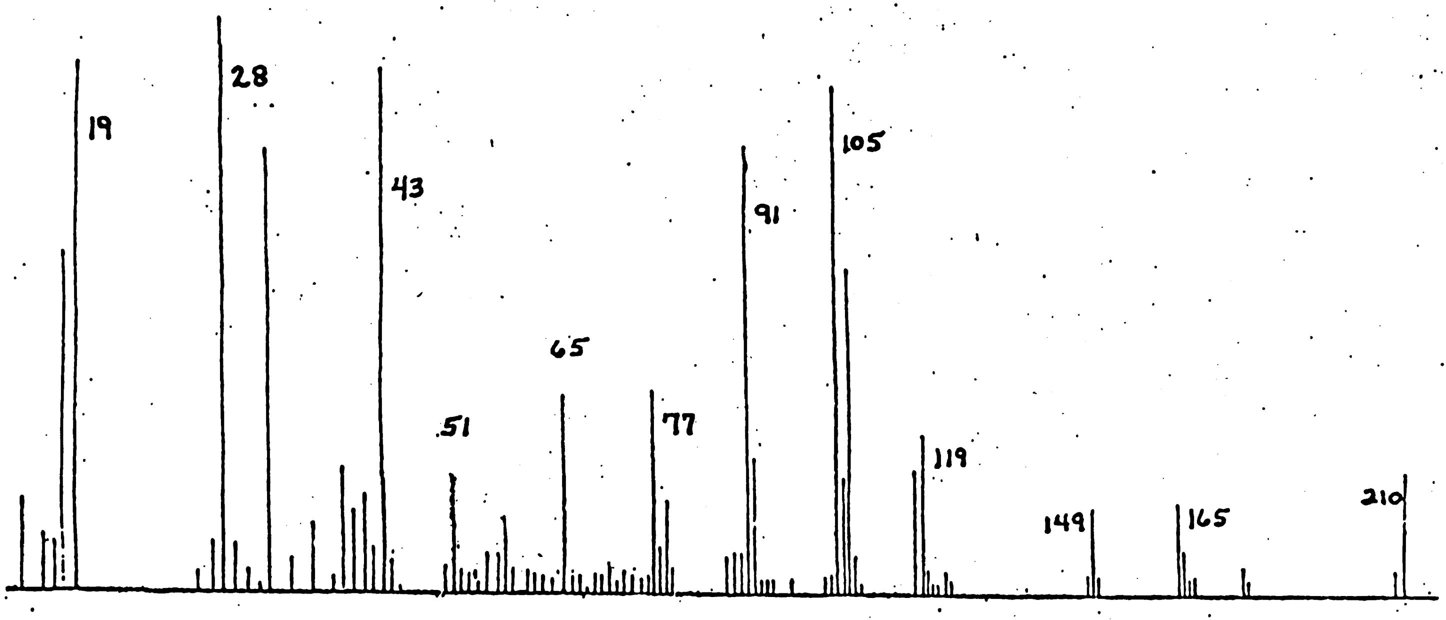
MASS SPECTRUM
PRODUCT 7

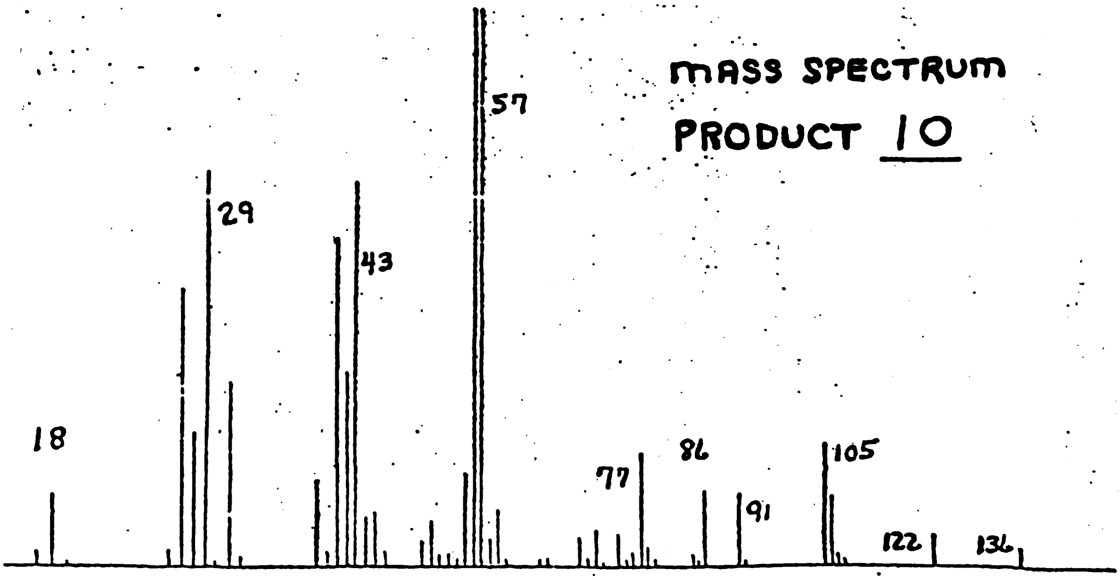
* GLUTARATE FRAGMENTS



MASS SPECTRUM
PRODUCT 8

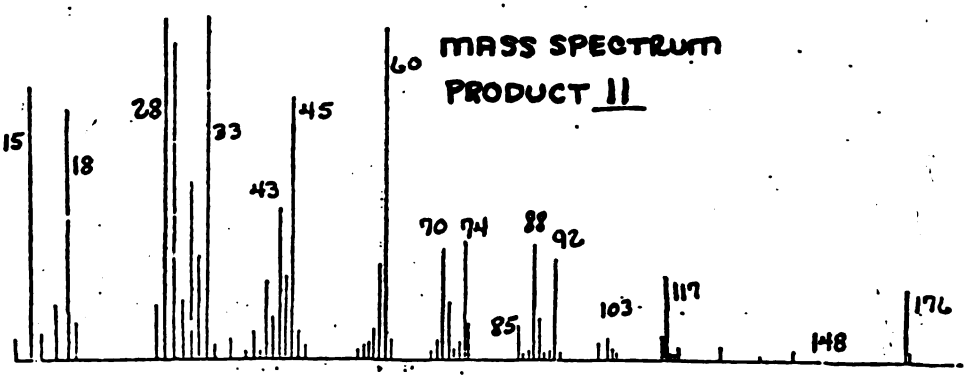
MASS SPECTRUM
PRODUCT 9



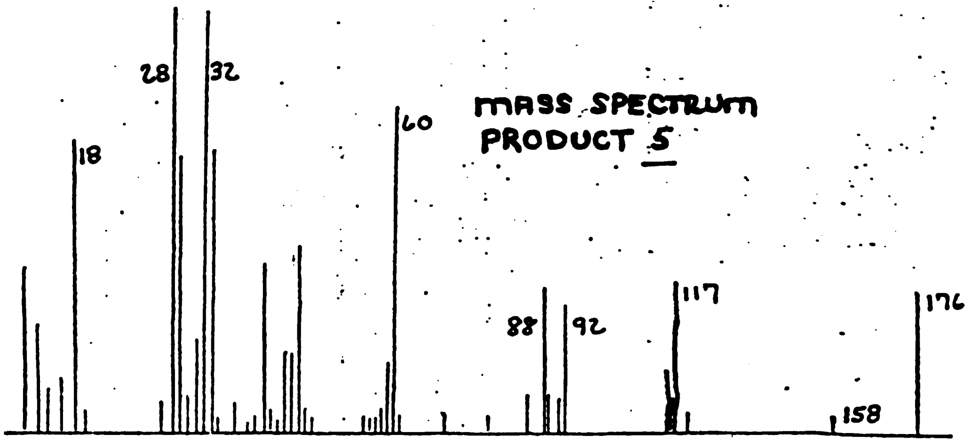

MASS SPECTRUM
PRODUCT 10
18
29
43
57
77
86
91
105
122
136

APPENDIX FOR SECTION C

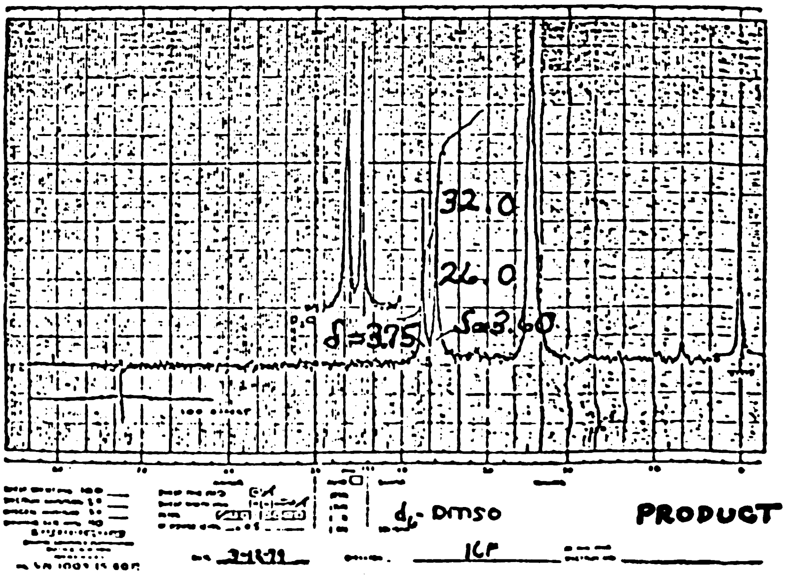
REACTION OF OCTAHYDROXYCYCLOBUTANE WITH ALCOHOLS, ACID ANHYDRIDES, AND ACETALS



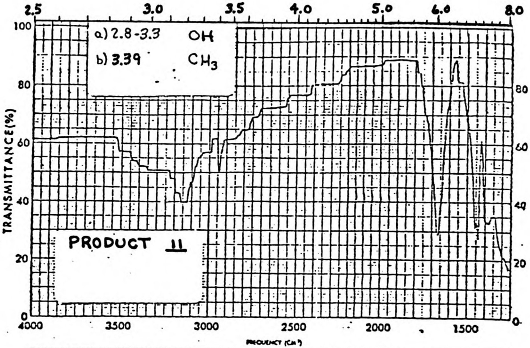
MASS SPECTRUM
PRODUCT 11



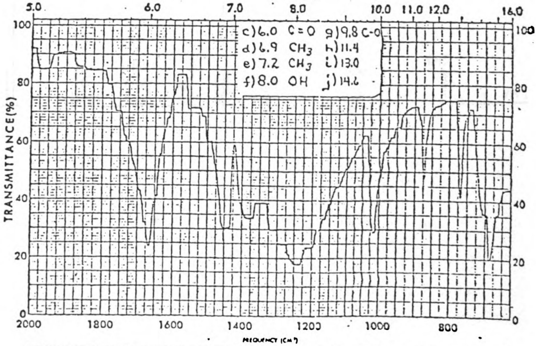
MASS SPECTRUM
PRODUCT 5



PRODUCT 11

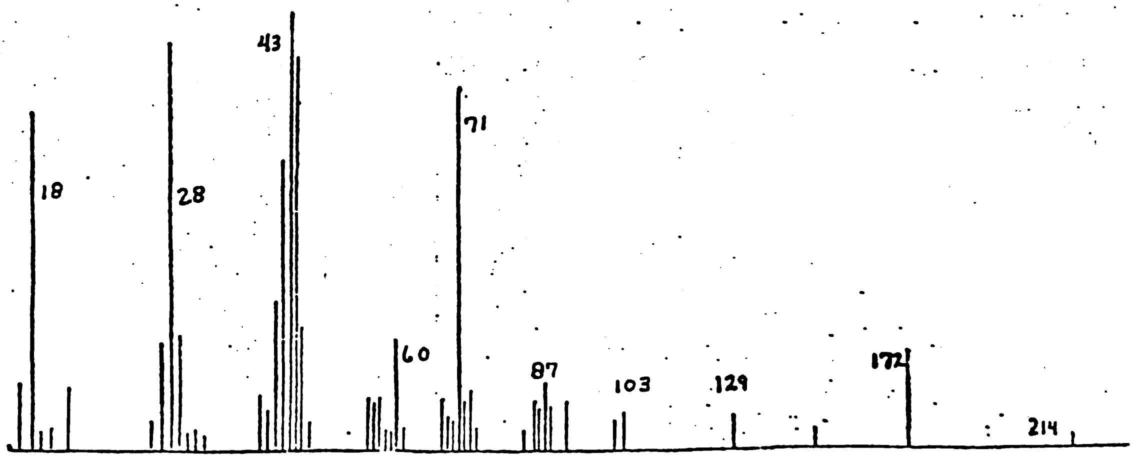


SAMPLE
ORIGIN
SOLVENT KBR
CURVE NO.
CONC.
CELL PATH
REFERENCE
SCAN SPEED FAST
SLIT N
OPERATOR KF
DATE 3-13-79
REMARKS



SAMPLE PRODUCT 11
ORIGIN
SOLVENT KBR
CURVE NO.
CONC.
CELL PATH
REFERENCE
SCAN SPEED FAST
SLIT N
OPERATOR KF
DATE 3-13-79
REMARKS

MASS SPECTRUM
PRODUCT 12

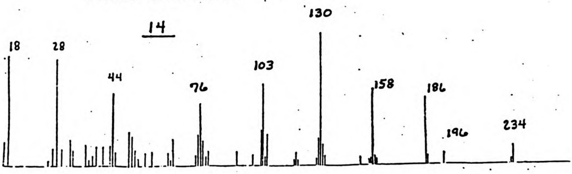


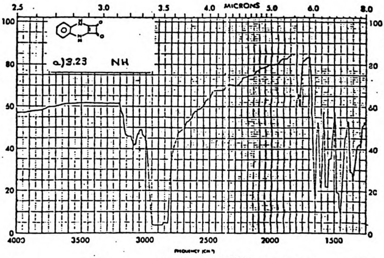
APPENDIX FOR SECTION D

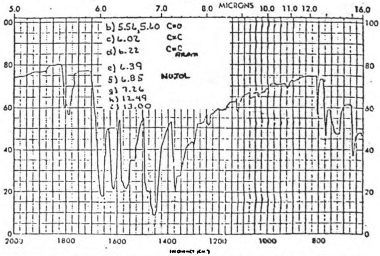
REACTIONS OF OCTAHYDROXYCYCLOBUTANE WITH O-PHENYLENEDIAMINE

MASS SPECTRUM

14





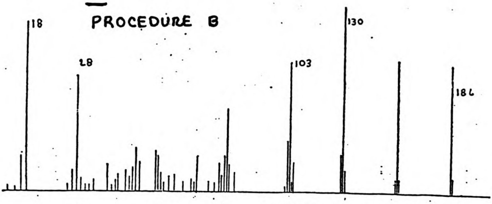


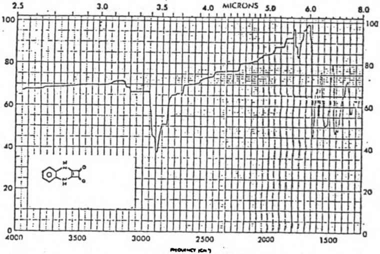
14 NUJOL	—	SLOW N	KF 1-31-79

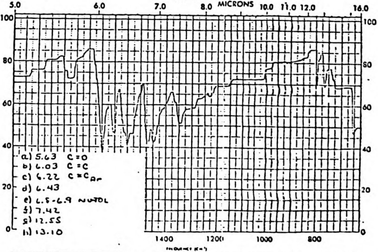
MASS SPECTRUM

14

PROCEDURE B





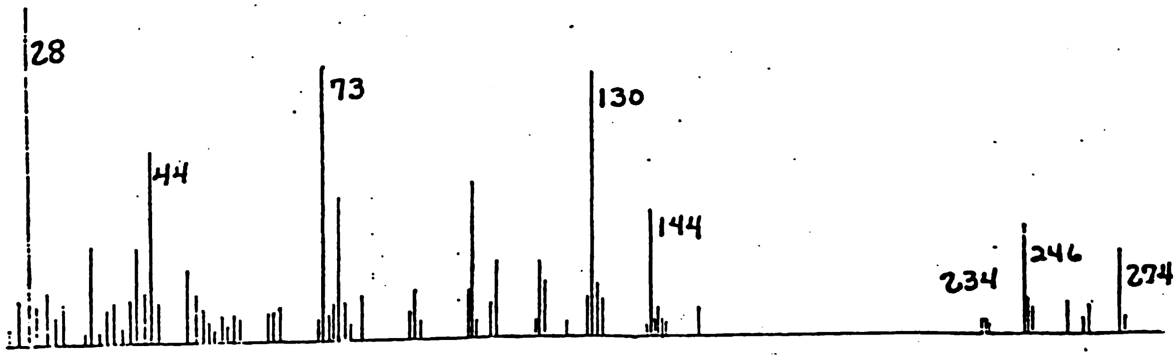


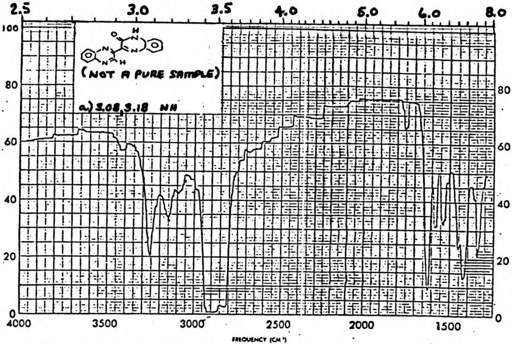
a) 5.63 C=O
b) 6.03 C=C
c) 6.22 $C=C_{Ar}$
d) 6.43
e) 6.5-6.9 NUJOL
f) 7.42
g) 12.55
h) 13.10

14
PROCEDURE B
NUJOL
SLOW
N
KF
3-16-79

MASS SPECTRUM

PRODUCT 19

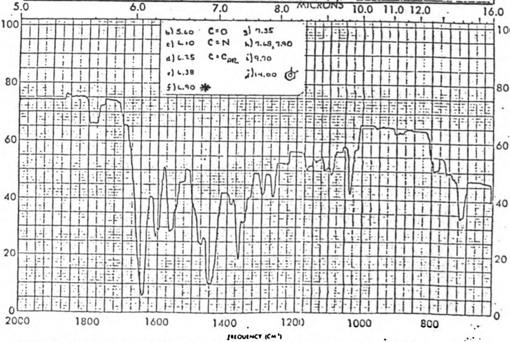




(NOT A PURE SAMPLE)

a) 3.08, 3.18 NH

SAMPLE PRODUCT 19	CURVE NO. –	SCAN SPEED Slow	OPERATOR KF
ORIGIN –	CONC. –	SLIT N	DATE 2-9-79
SOLVENT NUJOL	CELL PATH –	REMARKS	
	REFERENCE –		

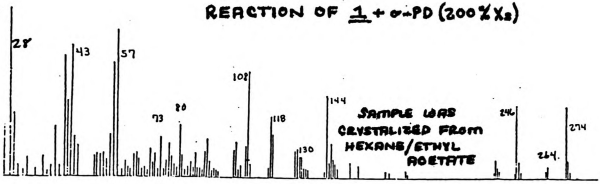


b) 5.60 C=O
c) 6.10 C=N
d) 6.25 $C=C_{AR}$
e) 6.38
f) 6.90 *
g) 7.35
h) 7.68, 7.90
i) 9.70
j) 14.00

SAMPLE PRODUCT 19	CURVE NO. –	SCAN SPEED SLOW	OPERATOR KF
ORIGIN –	CONC. –	SLIT N	DATE 2-9-79
SOLVENT NUJOL*	CELL PATH –	REMARKS	
	REFERENCE –		

MASS SPECTRUM

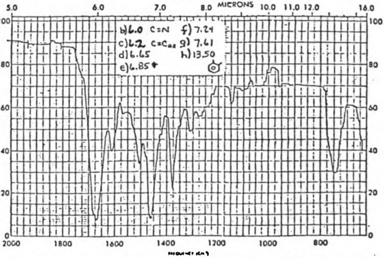
REACTION OF <u>1</u> + o-PD (200% X_s)



SAMPLE WAS CRYSTALIZED FROM HEXANE/ETHYL ACETATE

REACTION PRODUCTS
<u>1</u> + o-PD

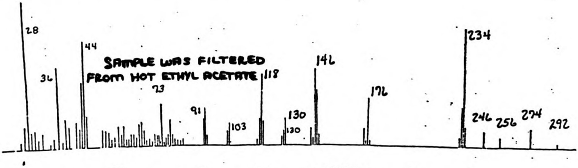
a) 3.0-3.3 OH

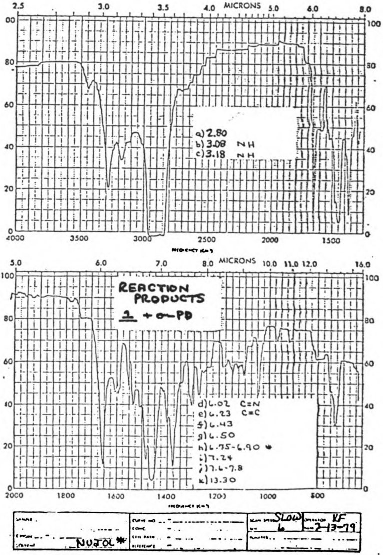


b) 6.0 C=N
c) 6.2 C=C$_{AR}$
d) 6.65
e) 6.85*
f) 7.24
g) 7.61
h) 13.50

SLOW
6
KF
NUJOL

MASS SPECTRUM
REACTION OF 1 + o-PD (200% Xs.)


SAMPLE WAS FILTERED FROM HOT ETHYL ACETATE


REACTION PRODUCTS 1 + o-PD

a) 2.80
b) 3.08 NH
c) 3.18 NH
d) 6.02 C=N
e) 6.23 C=C
f) 6.43
g) 6.50
h) 6.75-6.90 *
i) 7.24
j) 7.6-7.8
k) 13.30

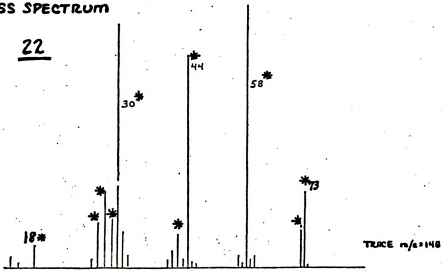
NUJOL*
SLOW
6
KF
2-13-79

APPENDIX FOR SECTION E

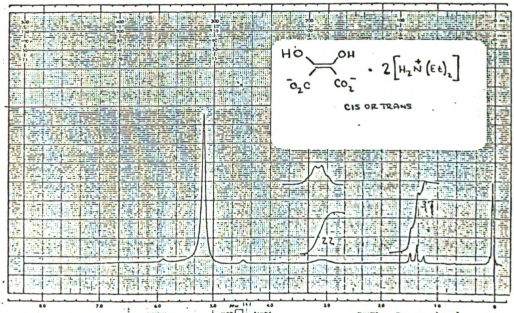
REACTIONS OF OCTAHYDROXYCYCLOBUTANE WITH 2° AMINES

MASS SPECTRUM

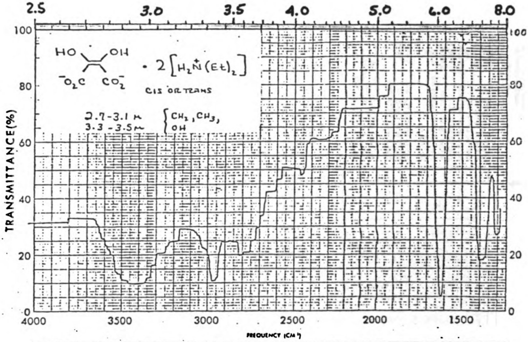
22



* INDICATES DIETHYLAMINE FRAGMENT



SWEEP OFFSET (Hz) 0
SPECTRUM AMPLITUDE .50
INTEGRAL AMPLITUDE
SPINNING RATE (RPS) 42
MANUAL
SWEEP TIME (SEC)
SWEEP WIDTH (Hz)
FILTER
RF POWER LEVEL .05
AUTO ☐
(250)
(500)
(.1)
(.05)
SAMPLE
SOLVENT $CF_3C(OH)_2CF_3 \cdot \frac{1}{2}H_2O$
REMARKS $\delta = 1.38$ (CH_3)
$\delta = 3.10$ (CH_2)
$CH_2/CH_3 = 1.5$ THEORY
1.68 ACTUAL
DATE 3-1-79
OPERATOR KF
SPECTRUM NO. 22
ELECTRONIC CHARTS
GRAPHIC CONTROLS CORPORATION
BUFFALO, NEW YORK
No VN 1009 (S-60T)

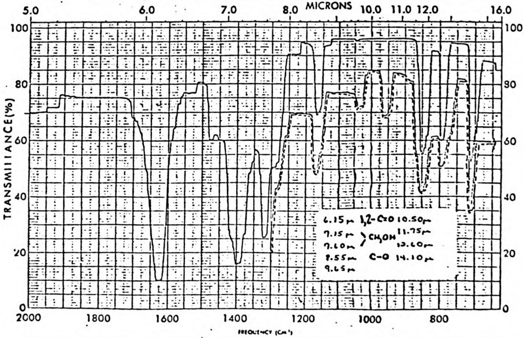


$\cdot\ 2\left[H_2\overset{+}{N}(Et)_2\right]$

CIS OR TRANS

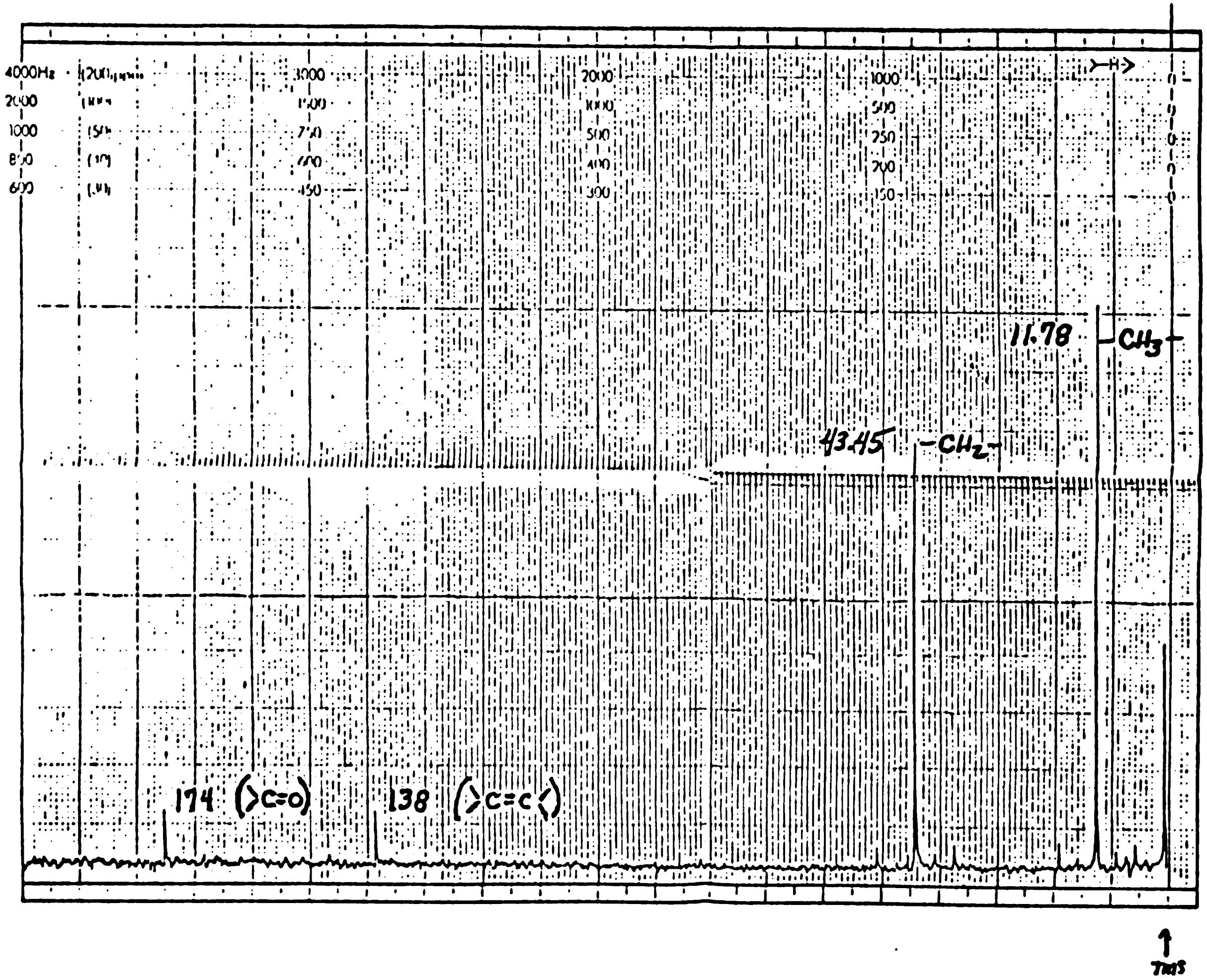
2.7-3.1 µ
3.3-3.5 µ } CH_2, CH_3, OH

SAMPLE 22	CURVE NO. –	SCAN SPEED Slow	OPERATOR KF
	CONC. –	SLIT 6	DATE 2-22-79
ORIGIN –	CELL PATH –	REMARKS	
SOLVENT KBr	REFERENCE –		



6.15 µ 1,2-C=O 10.50 µ
7.15 µ } CH_2OH 11.75 µ
7.60 µ 12.60 µ
8.55 µ C-O 14.10 µ
9.65 µ

SAMPLE 22	CURVE NO. –	SCAN SPEED Slow	OPERATOR KF
	CONC. –	SLIT 6	DATE 2-22-79
ORIGIN –	CELL PATH –	REMARKS	
SOLVENT KBr	REFERENCE –		



SPECTRUM NO.

OPERATOR ____ DATE

SAMPLE 22

C13 NMR

LOCK SIGNAL —
SPIN RATE — rps TEMP 2

ACQUISITION
SPECTRAL WIDTH (SW) 4000
NO. OF TRANSIENTS (N 0
ACQUISITION TIME (AT) 1.023
PULSE WIDTH (PW) 6
PULSE DELAY (PD) 0
DATA POINTS (DP) 8192

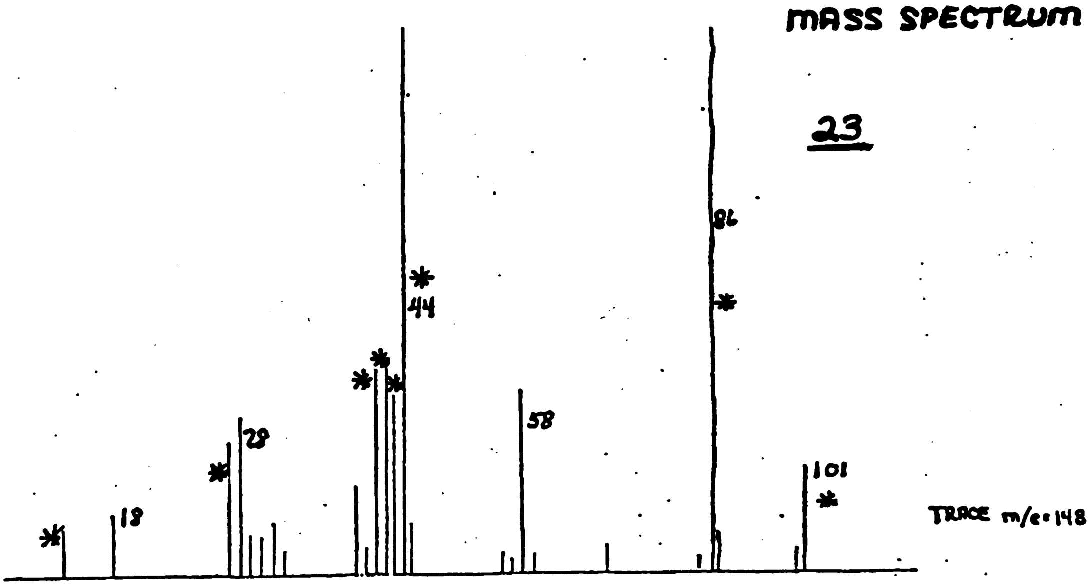
TRANSMITTER OFFSET (TO) 51
HIGH FIELD 1 LOW FIELD
RECEIVER GAIN (RG) 4

DECOUPLER MODE (DM) 1
DECOUPLER OFFSET (DO) 50
NOISE BANDWIDTH (NB) 100

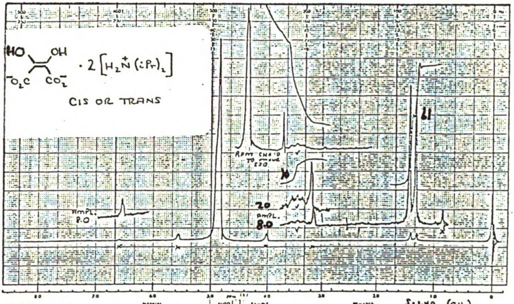
DISPLAY
SENS ENHANCEMENT (SE) .4
WIDTH OF PLOT (WP) 4000
END OF PLOT (EP) 5
WIDTH OF CHART (WC) 4000
END OF CHART (EC) 5
VERTICAL SCALE (VS) 1.00
REFERENCE LINE (RL) 0

MASS SPECTRUM

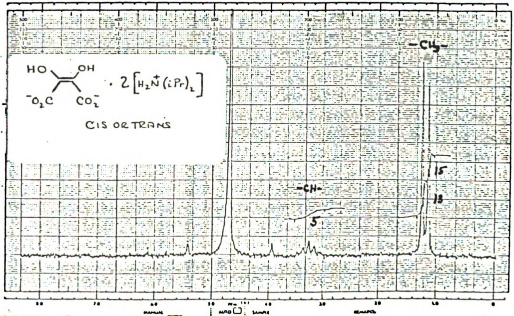
23



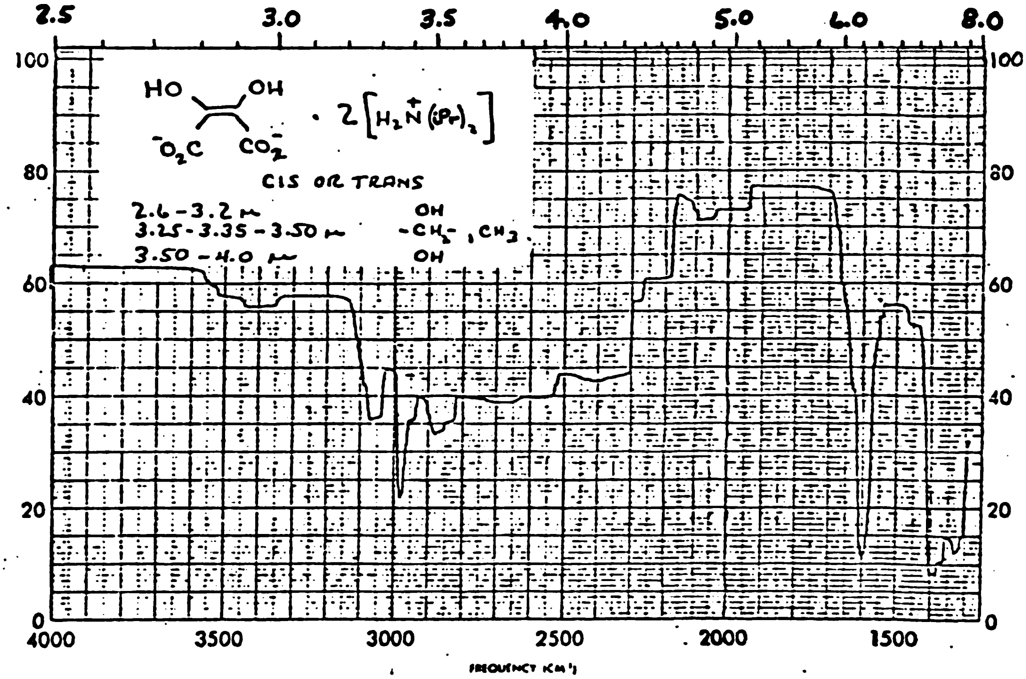
* INDICATES DIISOPROPYLAMINE FRAGMENTS



MANUAL
SWEEP OFFSET (Hz) 0
SPECTRUM AMPLITUDE 50
INTEGRAL AMPLITUDE 80
SPINNING RATE (RPS) 50
SWEEP TIME (SEC)
SWEEP WIDTH (Hz)
FILTER
RF POWER LEVEL .05
AUTO ☐
(250)
(500)
(.1)
(.05)
SAMPLE
SOLVENT $CF_3C(OH)_2CF_3 \cdot \frac{1}{2}H_2O$
REMARKS δ = 1.40 (CH_3)
δ = 3.45 (CH)
THEORY = 6/1 ACTUAL 6.1/1
GRAPHIC CONTROLS CORPORATION
BUFFALO, NEW YORK
PRINTED IN U.S.A.
DATE 3-7-79
OPERATOR KF
60 MHz NMR SPECTRUM NO. 23



MANUAL
SWEEP OFFSET (Hz) 0
SPECTRUM AMPLITUDE 20
INTEGRAL AMPLITUDE -
SPINNING RATE (RPS) 45
SWEEP TIME (SEC)
SWEEP WIDTH (Hz)
FILTER
RF POWER LEVEL .05
AUTO ☐
(250)
(500)
(.1)
(.05)
SAMPLE
SOLVENT $CF_3C(OH)_2CF_3 \cdot \frac{1}{2}H_2O$
REMARKS
CH_3/CH = 6.0 THEORY
CH_3/CH = 6.6 ACTUAL
GRAPHIC CONTROLS CORPORATION
BUFFALO, NEW YORK
PRINTED IN U.S.A.
NO. VN 1009 (S-60T)
DATE 3-8-79
OPERATOR KF
60 MHz NMR SPECTRUM NO. 23



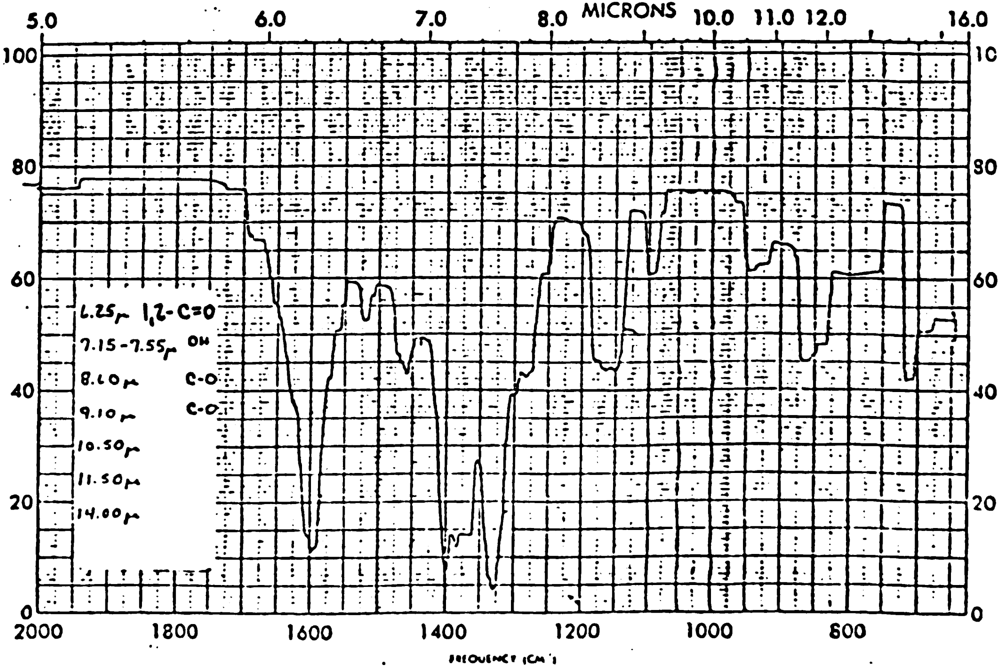
CIS OR TRANS

2.6-3.2 µ OH

3.25-3.35-3.50 µ $-CH_2-$, CH_3

3.50-4.0 µ OH

SAMPLE 23	CURVE NO. –	SCAN SPEED Slow	OPERATOR KF
	CONC. –	SLIT 6	DATE 3-8-79
ORIGIN –	CELL PATH –	REMARKS	
SOLVENT KBr	REFERENCE –		



6.25µ 1,2-C=O

7.15-7.55µ OH

8.60µ C-O

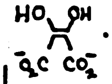
9.10µ C-O

10.50µ

11.50µ

14.00µ

SAMPLE 23	CURVE NO. –	SCAN SPEED Slow	OPERATOR KF
	CONC. –	SLIT 6	DATE 3-9-79
ORIGIN –	CELL PATH –	REMARKS	
SOLVENT KBr	REFERENCE –		



$\cdot 2[H_2\overset{+}{N}(iPr)_2]$

CIS OR TRANS

3.15 - 4.80μ OH, CH
6.28 μ 1,2- C=O
7.55 μ OH, CH
8.55 μ C-O
9.00 μ
10.40 μ 12.50 μ
11.40 μ 14.00 μ

ORIGIN

PURITY

PHASE NUJOL

CONCENTRATION

THICKNESS

DATE 7-17-79

OPERATOR K.F.

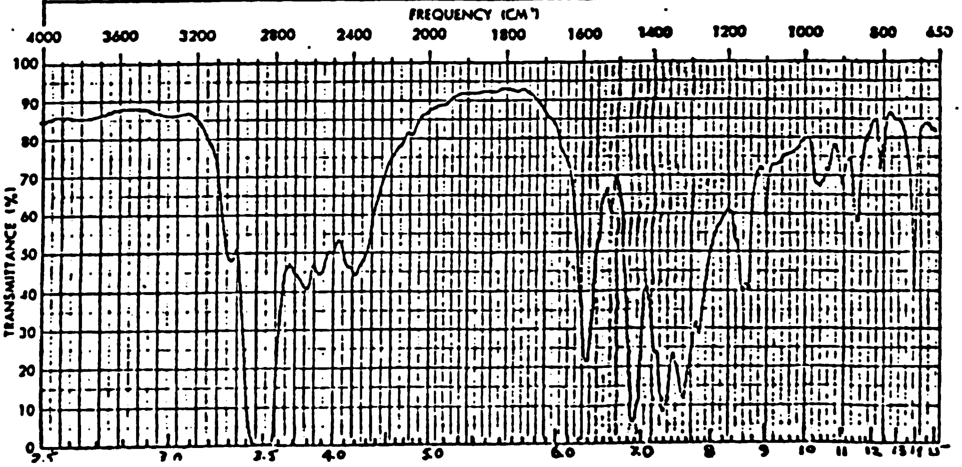
PERKIN-ELMER

MODEL 700

SPECTRUM NO. 23

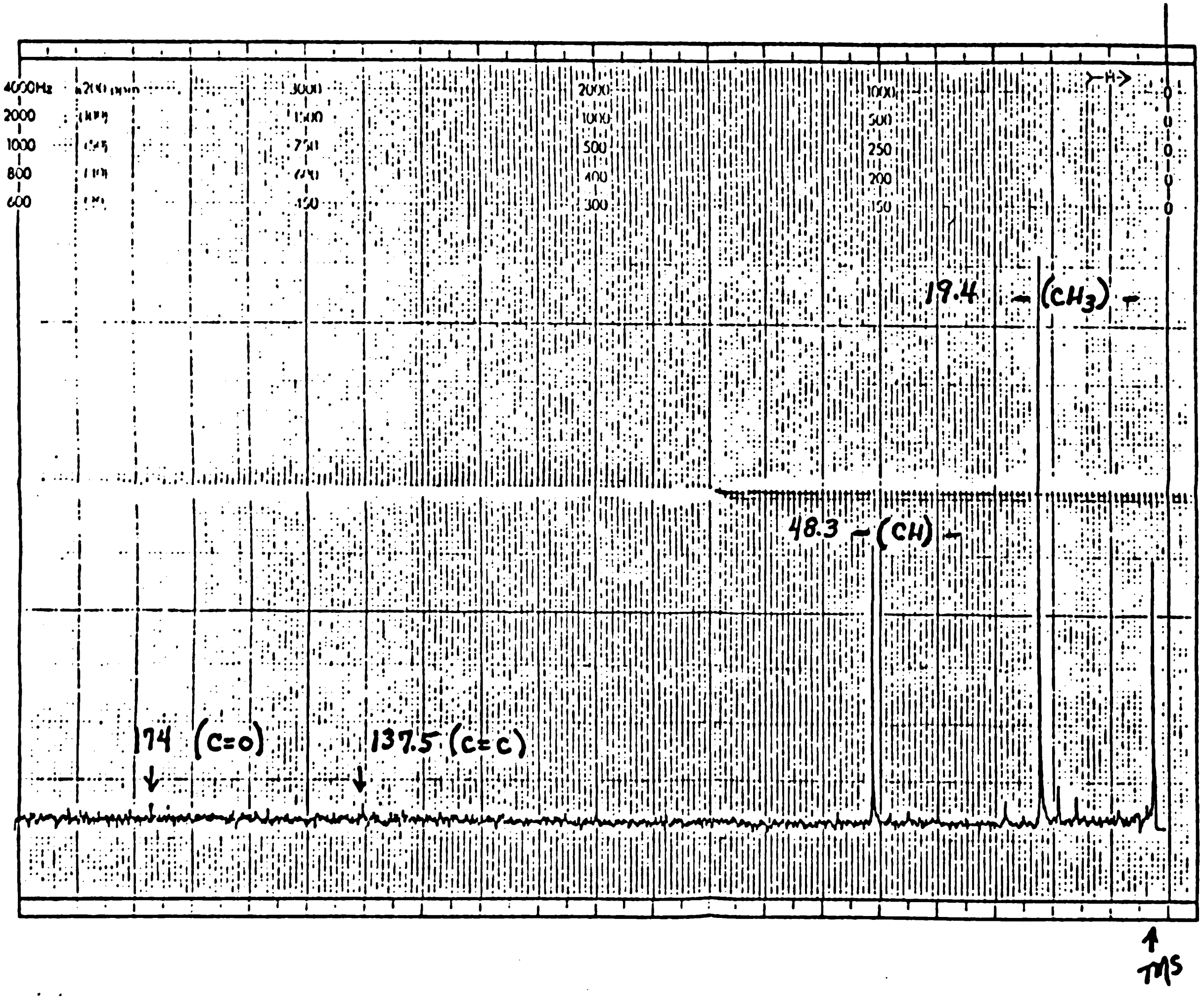
SAMPLE 1

SAMPLE 2



SAMPLE

SPECTRUM NO.



SPECTRUM NO.
OPERATOR . . . . **DA**

SAMPLE 23

C¹³ NMR

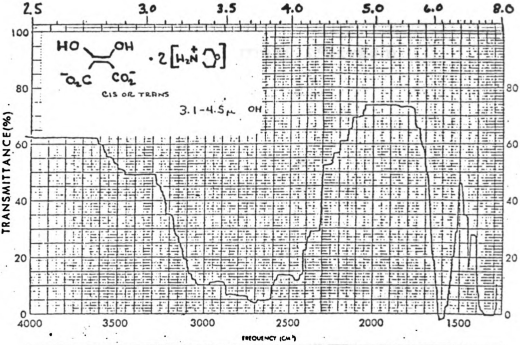
LOCK SIGNAL –
SPIN RATE – rps. TEMP

ACQUISITION
SPECTRAL WIDTH (SW) 4000
NO. OF TRANSIENTS (NT) 0
ACQUISITION TIME (AT) 1.02
PULSE WIDTH (PW) 5
PULSE DELAY (PD) 0
DATA POINTS (DP) 8192

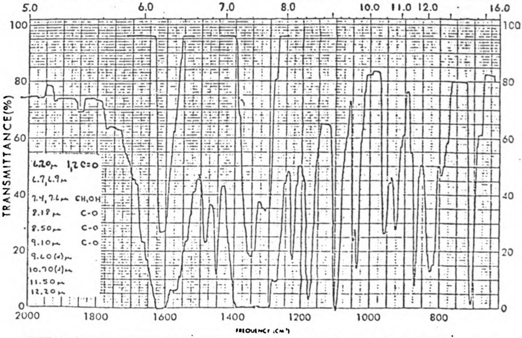
TRANSMITTER OFFSET (TO) 51
HIGH FIELD 1 LOW FIELD
RECEIVER GAIN (RG) 4

DECOUPLER MODE (DM) 1
DECOUPLER OFFSET (DO) 50
NOISE BANDWIDTH (NB) 100

DISPLAY
SENS. ENHANCEMENT (SE) .4
WIDTH OF PLOT (WP) 4000
END OF PLOT (EP) 39
WIDTH OF CHART (WC) 400
END OF CHART (EC) 37
VERTICAL SCALE (VS) 100
REFERENCE LINE (RL) 0



SAMPLE 24	CURVE NO. –	SCAN SPEED SLOW	OPERATOR KF
	CONC. –	SLIT 6	DATE 2-22-79
ORIGIN –	CELL PATH –	REMARKS	
SOLVENT KBr	REFERENCE –		

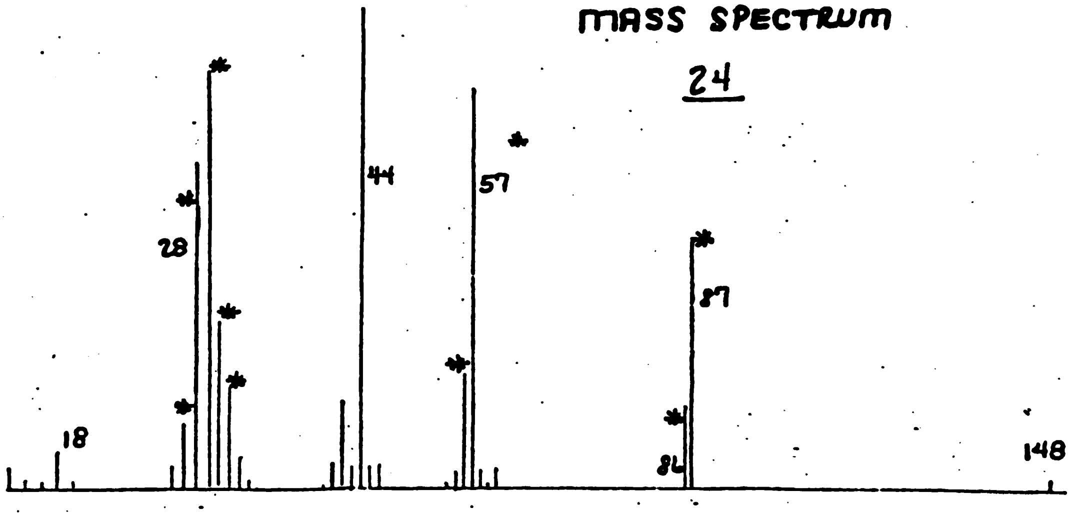


6.20μ	1,2 C=O
6.7, 6.9μ	
7.4, 7.6μ	CH, OH
8.18μ	C-O
8.50μ	C-O
9.10μ	C-O
9.60 (d)μ	
10.70 (d)μ	
11.50μ	
12.20μ	

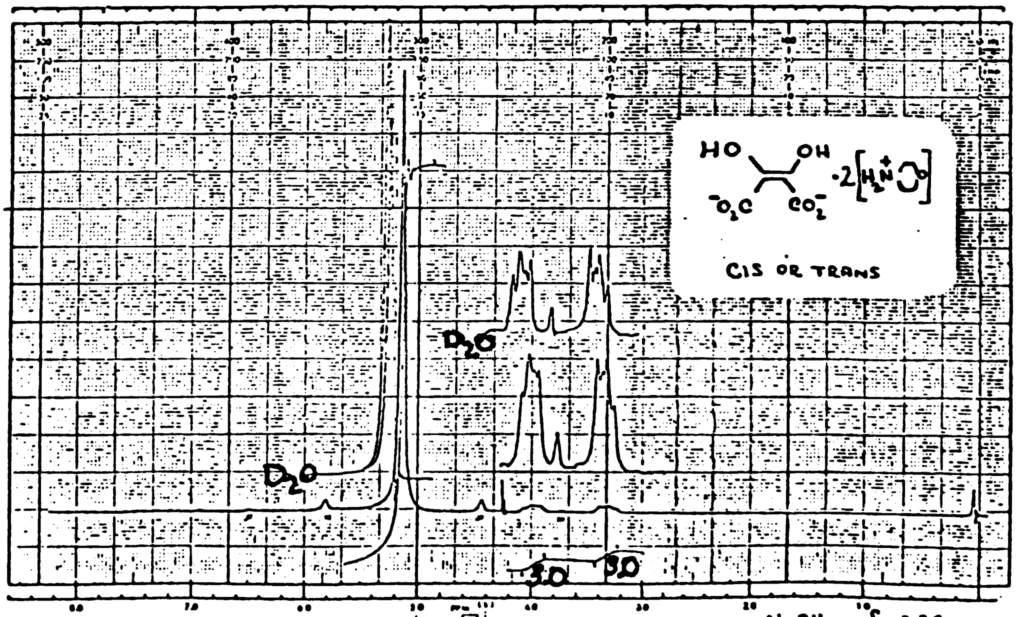
SAMPLE 24	CURVE NO. –	SCAN SPEED SLOW	OPERATOR KF
	CONC. –	SLIT 6	DATE 2-22-79
ORIGIN –	CELL PATH –	REMARKS	
SOLVENT KBr	REFERENCE –		

MASS SPECTRUM

24



* INDICATES A MORPHOLINE FRAGMENT



SWEEP OFFSET (Hz) 0

SPECTRUM AMPLITUDE 40

INTEGRAL AMPLITUDE –

SPINNING RATE (rps) 4L

MANUAL

SWEEP TIME (SEC)

SWEEP WIDTH (Hz)

FILTER

RF POWER LEVEL .05

AUTO ☐

SAMPLE

REMARKS N-CH₂ δ = 3.38

O-CH₂ δ = 4.00

SOLVENT $CF_3C(OH)_2CF_3 \cdot \frac{1}{2}H_2O$

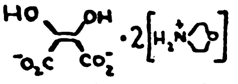
DATE 3-1-71

OPERATOR K.F.

SPECTRUM NO. 24

No VN 1009 (5-60T)

NO. 007-1061



CIS OR TRANS

3.1-4.0μ OH
6.20μ C=O 10.4μ
8.10μ C-O 10.7μ
8.45μ C-O 11.4μ
9.00μ 11.9μ
9.60μ 12.5μ
14.2μ

ORIGIN

PURITY -

PHASE NUJOL

CONCENTRATION

THICKNESS

DATE 9-17-79

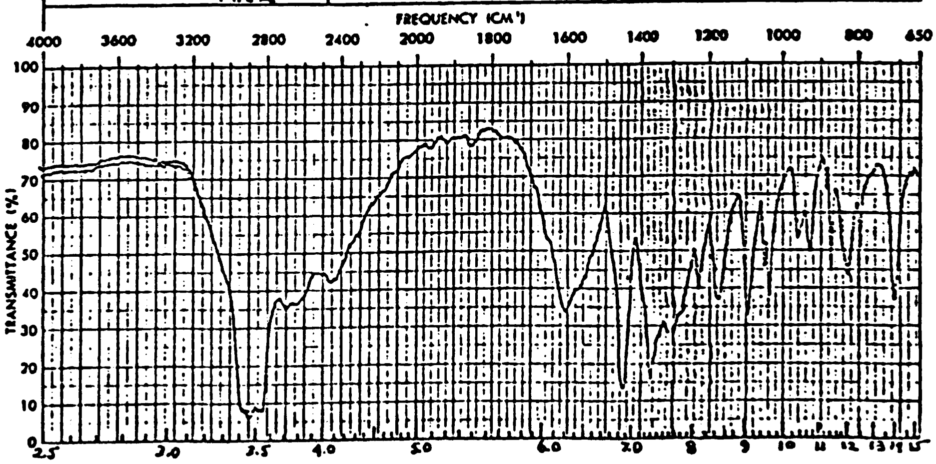
OPERATOR KF

PERKIN-ELMER
MODEL 700

SPECTRUM NO. 24

SAMPLE 1

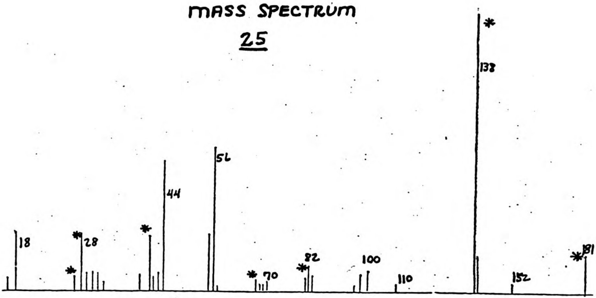
SAMPLE 2



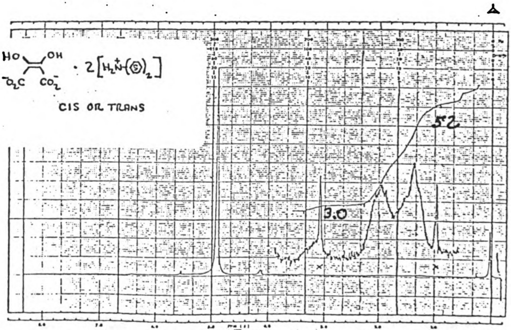
SAMPLE —— SPECTRUM NO. ——

MASS SPECTRUM

25



* INDICATES DICYCLOHEXYLAMINE FRAGMENTS



SWEEP OFFSET (Hz) 0
SPECTRUM AMPLITUDE 32
INTEGRAL AMPLITUDE –
SPINNING RATE (RPS) 90

SWEEP TIME (SEC)
SWEEP WIDTH (Hz)
FILTER
RF POWER LEVEL 95

AUTO ☐

SAMPLE

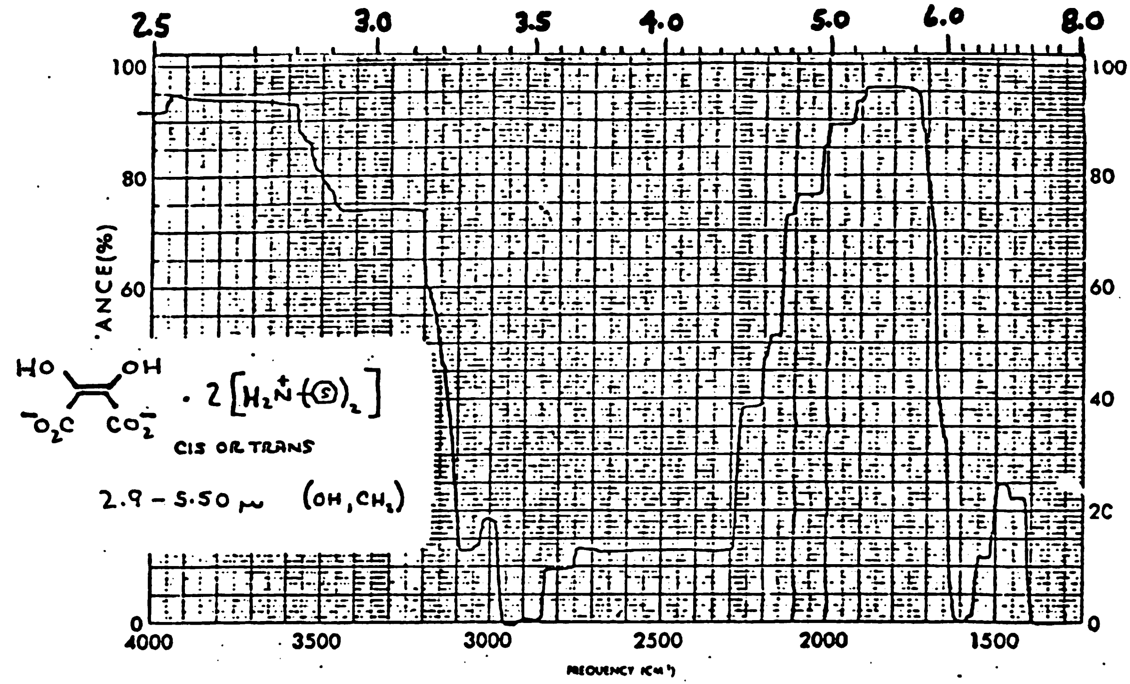
δ 1.0 TO 2.4 (CYL. C_6H_{11})

SOLVENT $CF_3C(OH)_2CF_3 \cdot \frac{1}{2} H_2O$

DATE 3-9-79

OPERATOR XF

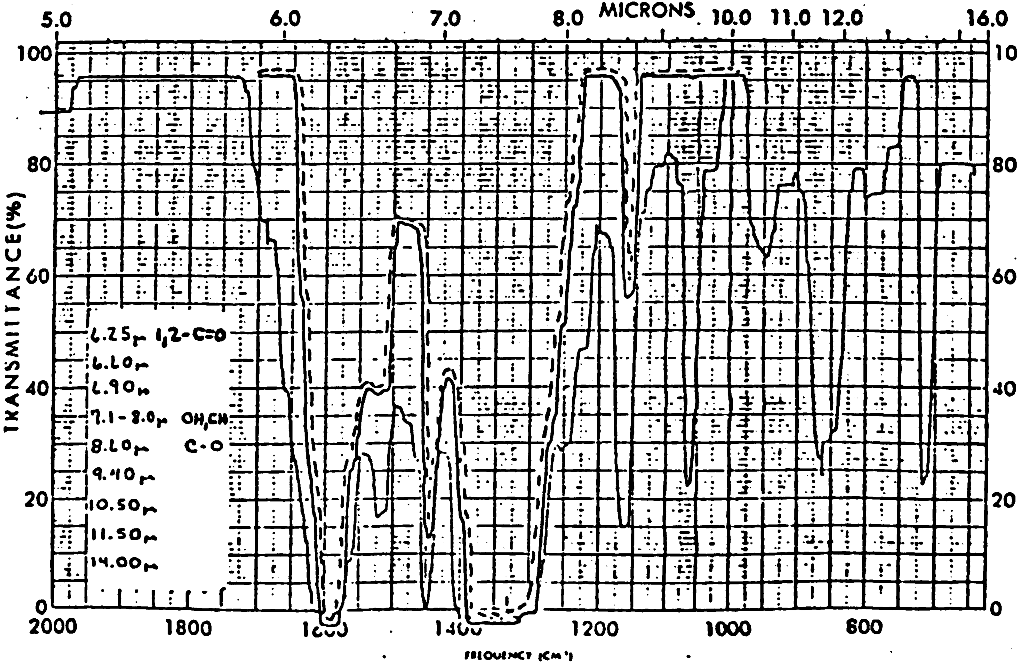
SPECTRUM NO. 25



CIS OR TRANS

2.9 - 5.50 μ (OH, CH_3)

SAMPLE 25
ORIGIN —
SOLVENT KBr
CURVE NO. —
CONC. —
CELL PATH —
REFERENCE —
SCAN SPEED Slow
SLIT 6
REMARKS
OPERATOR KF
DATE 3-7-79

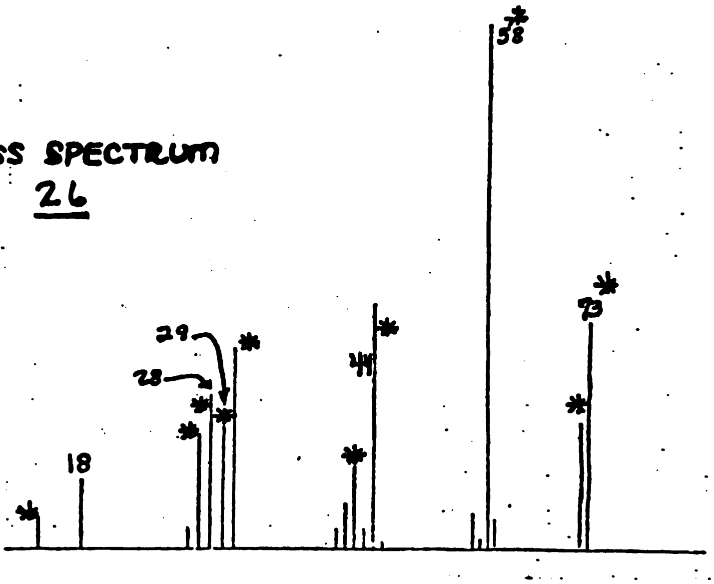


6.25μ 1,2-C=O
6.60μ
6.90μ
7.1-8.0μ OH,CH
8.60μ C-O
9.40μ
10.50μ
11.50μ
14.00μ

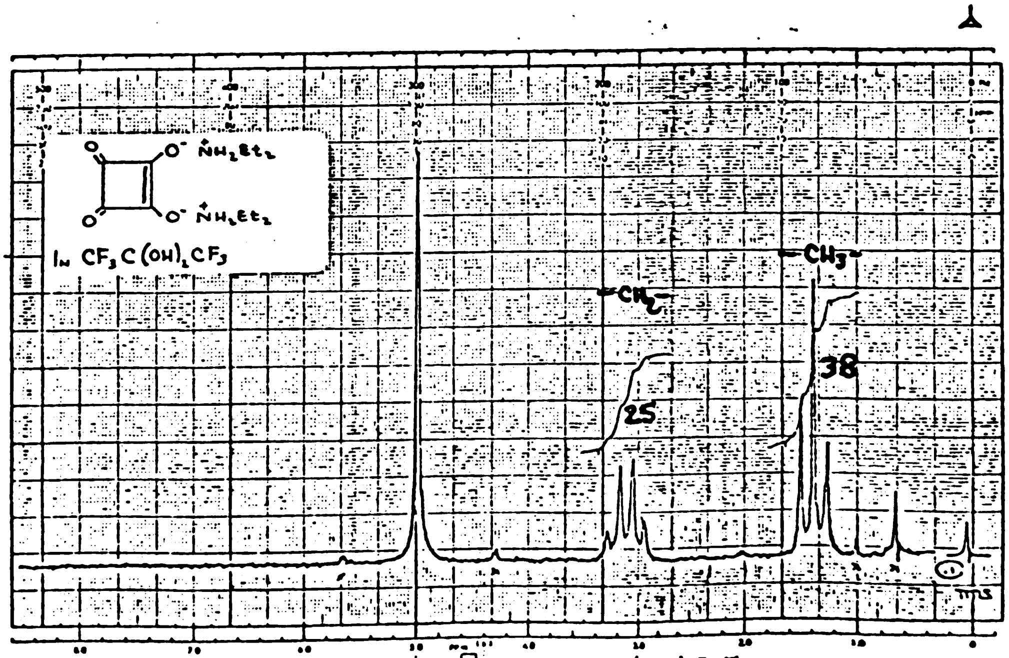
SAMPLE 25
ORIGIN —
SOLVENT KBr
CURVE NO. —
CONC. —
CELL PATH —
REFERENCE —
SCAN SPEED Slow
SLIT 6
REMARKS
OPERATOR KF
DATE 3-7-79

MASS SPECTRUM

26



* INDICATES DIETHYLAMINE FRAGMENTS



$CH_3/CH_2 = 3/2$

ACTUAL = 3.04/2

SWEEP OFFSET 0

SPECTRUM AMPLITUDE 1.0

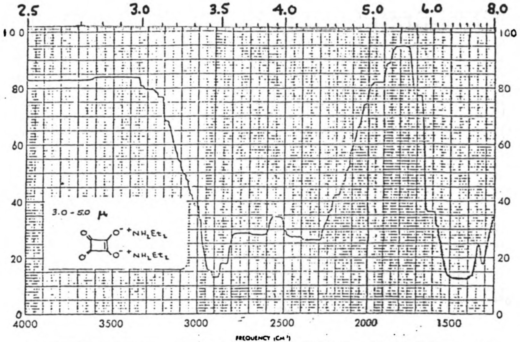
SPINNING RATE 40

No. VN 1009 (S-60T)

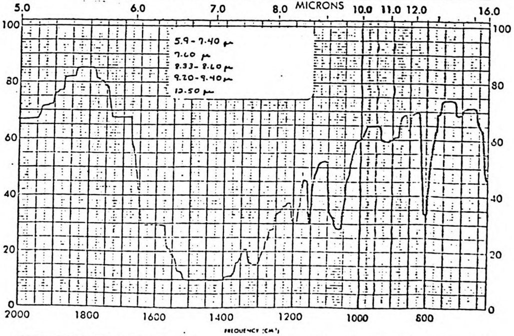
DATE 9-12-79

OPERATOR KF

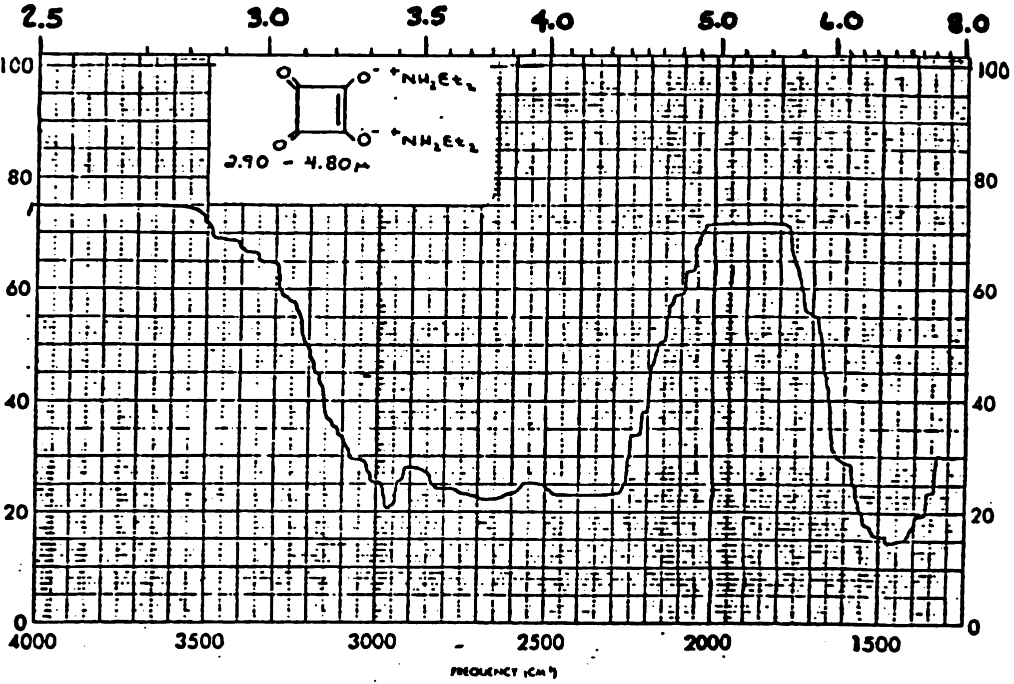
SPECTRUM NO. 26



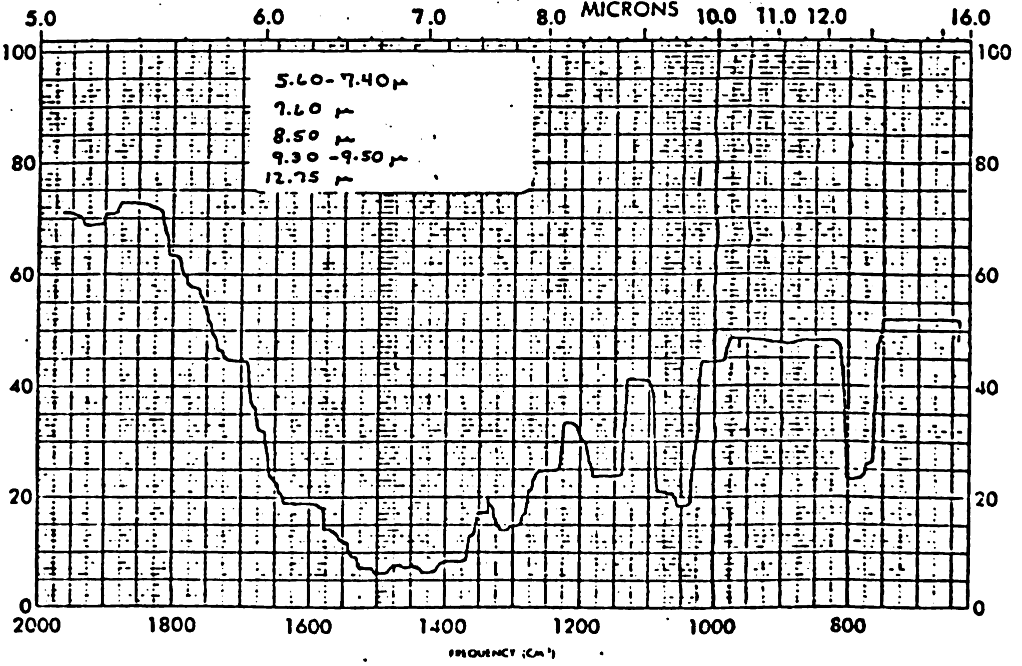
SAMPLE 26	CURVE NO. –	SCAN SPEED Slow	OPERATOR FEY
	CONC –	SLIT N	DATE 3-13-79
ORIGIN –	CELL PATH –	REMARKS	
	REFERENCE –		



SAMPLE 26	CURVE NO. –	SCAN SPEED Slow	OPERATOR FEY
	CONC –	SLIT N	DATE 3-13-79
ORIGIN –	CELL PATH –	REMARKS	
SOLVENT Nujol	REFERENCE –		



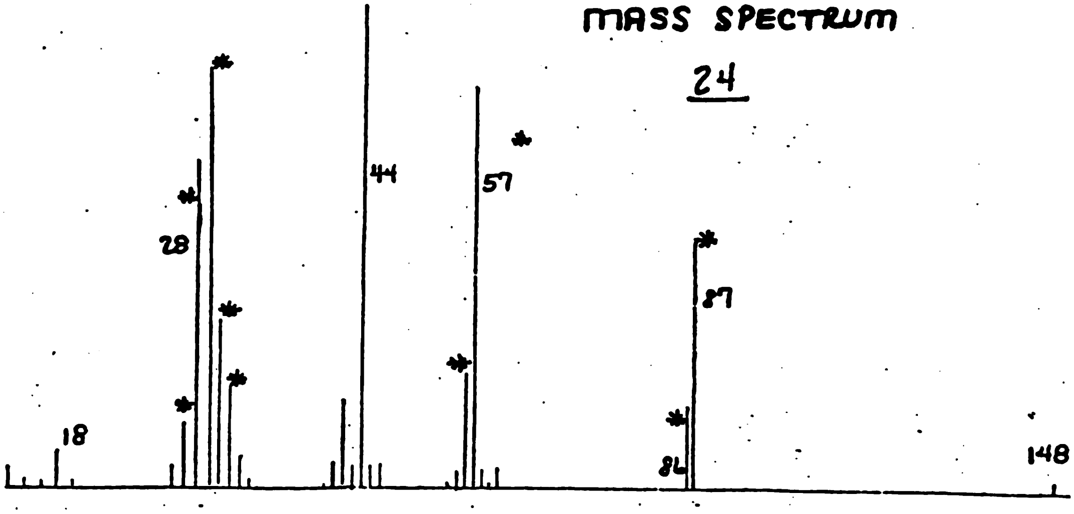
SAMPLE 26	CURVE NO. —	SCAN SPEED Slow	OPERATOR EF
	CONC. —	SLIT 6	DATE 3-12-79
ORIGIN —	CELL PATH —	REMARKS	
SOLVENT KBR	REFERENCE —		



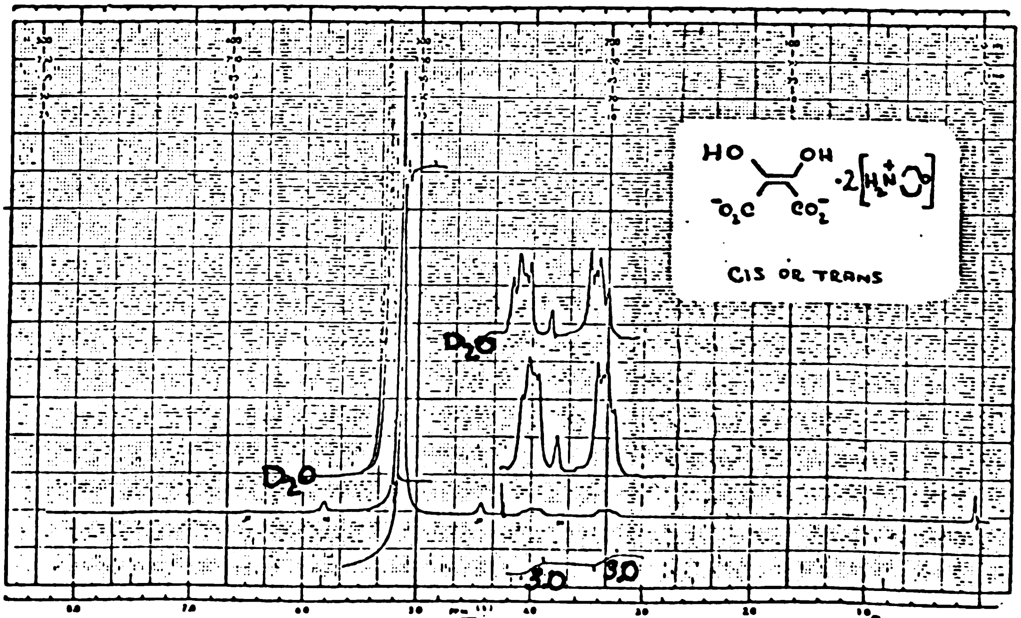
SAMPLE 26	CURVE NO. —	SCAN SPEED Slow	OPERATOR KF
	CONC. —	SLIT 6	DATE 3-12-79
ORIGIN —	CELL PATH —	REMARKS	
SOLVENT KBr	REFERENCE —		

MASS SPECTRUM

24



* INDICATES A MORPHOLINE FRAGMENT



SWEEP OFFSET (Hz) 0

SPECTRUM AMPLITUDE 40

INTEGRAL AMPLITUDE -

SPINNING RATE (RPS) 4L

MANUAL

SWEEP TIME (SEC)

SWEEP WIDTH (Hz)

FILTER

RF POWER LEVEL .05

AUTO ☐

SAMPLE

REMARKS N-CH₂ δ = 3.38

O-CH₂ δ = 4.00

SOLVENT $CF_3C(OH)_2CF_3 \cdot \frac{1}{2}H_2O$

DATE 3-7-79

OPERATOR K.F.

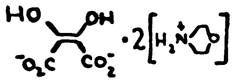
SPECTRUM NO. 24

GRAPHIC CONTROLS CORPORATION

BUFFALO NEW YORK

NO VN 1009 (S-60T)

NO. 007-1061



CIS OR TRANS

3.1-4.0µ	OH	
6.20µ	C=O	10.4µ
8.10µ	C-O	10.7µ
8.45µ	C-O	11.4µ
9.00µ		11.9µ
9.60µ		12.5µ
		14.2µ

ORIGIN

PURITY

PHASE NUJOL

CONCENTRATION

THICKNESS

DATE 9-17-79

OPERATOR KF

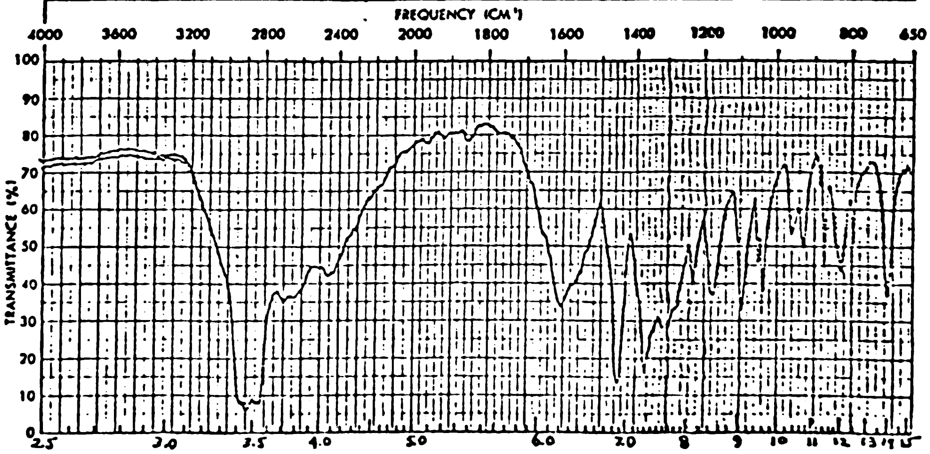
PERKIN-ELMER

MODEL 700

SPECTRUM NO. 24

SAMPLE 1

SAMPLE 2

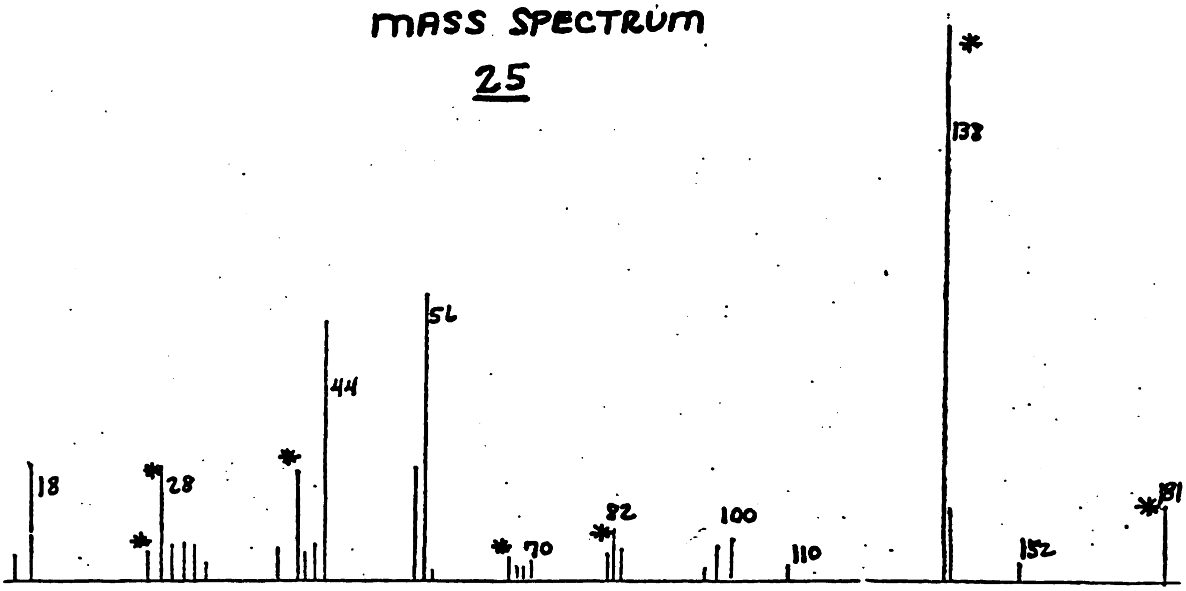


SAMPLE

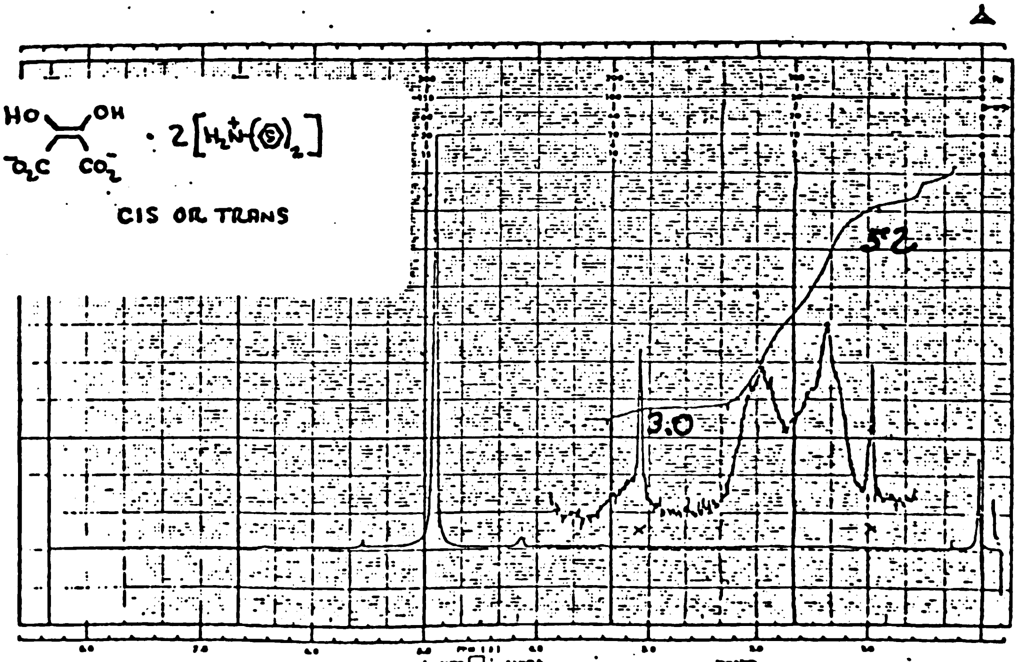
SPECTRUM NO.

MASS SPECTRUM

25



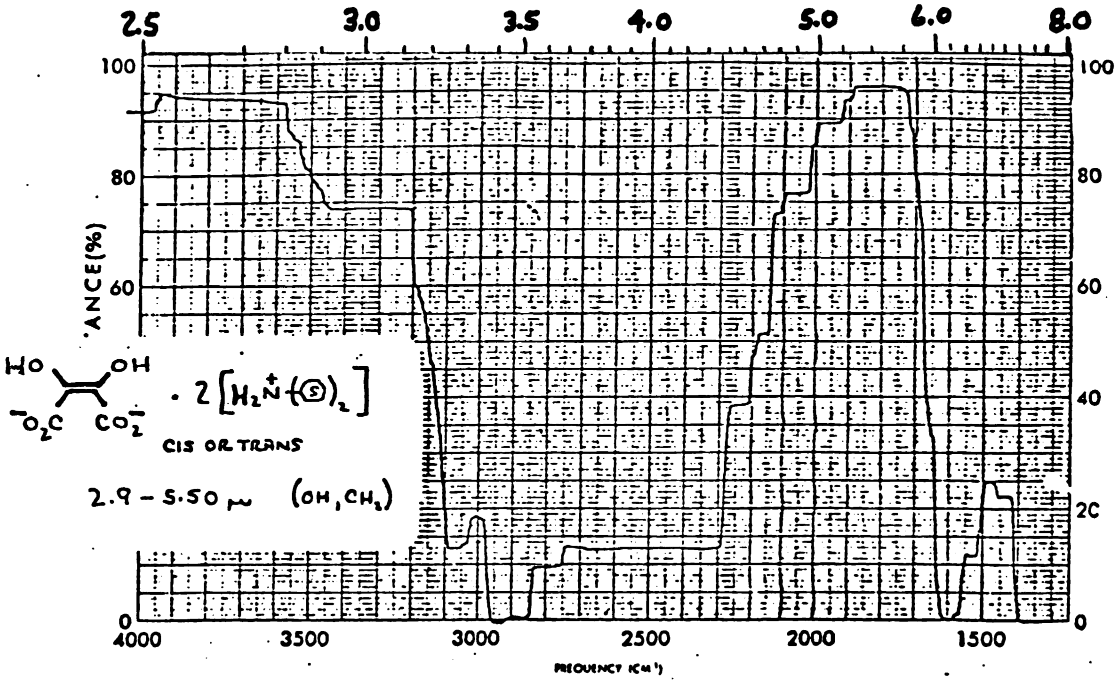
* INDICATES DICYCLOHEXYLAMINE FRAGMENTS



δ 1.0 TO 2.4 (CYL. C_6H_5)

$CF_3C(OH)_2CF_3 \cdot \frac{1}{2} H_2O$

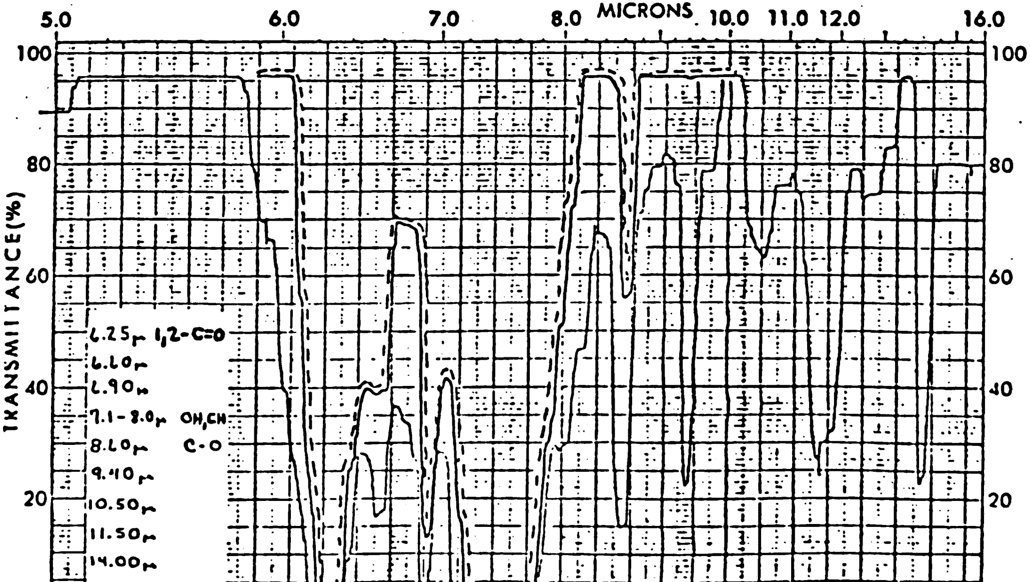
3-9-79 XF 25



CIS OR TRANS

2.9 - 5.50 μ (OH, CH₂)

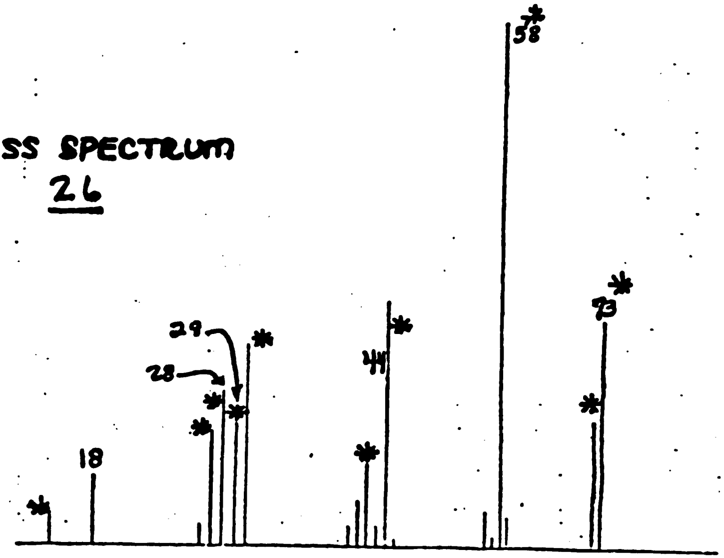
SAMPLE 25	CURVE NO. —	SCAN SPEED 3 [illegible]	OPERATOR KF
	CONC. —	SLIT 6	DATE 3-7-79
ORIGIN —	CELL PATH —	REMARKS	
SOLVENT KBr	REFERENCE —		



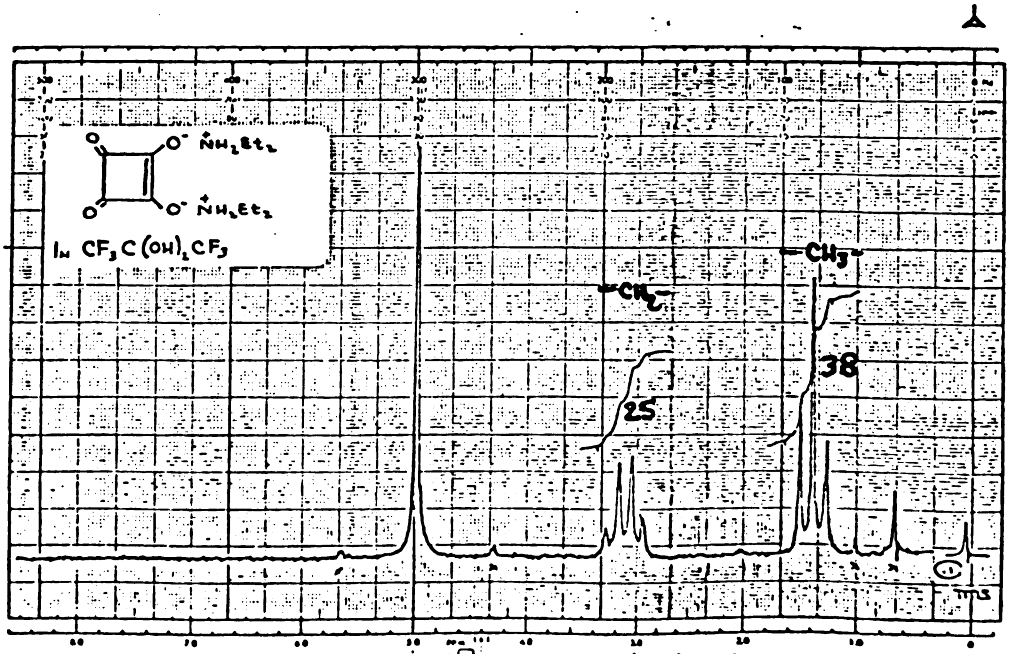
6.25μ 1,2-C=O
6.60μ
6.90μ
7.1-8.0μ OH,CH
8.60μ C-O
9.40μ
10.50μ
11.50μ
14.00μ

SAMPLE 25	CURVE NO —	SCAN SPEED 3 [illegible]	OPERATOR KF
	CONC —	SLIT 6	DATE 3-7-79
ORIGIN —	CELL PATH —	REMARKS	
SOLVENT KBr	REFERENCE —		

MASS SPECTRUM
26



* INDICATES DIETHYLAMINE FRAGMENTS



SWEEP OFFSET (Hz) 0
SPECTRUM AMPLITUDE 10
[illegible]
SPINNING RATE (rps) 40
[illegible]
NO. VN 1009 (5-60T)

SWEEP TIME [illegible]
SWEEP WIDTH [illegible]
FILTER [illegible]
RF POWER LEVEL [illegible]

AUTO ☐

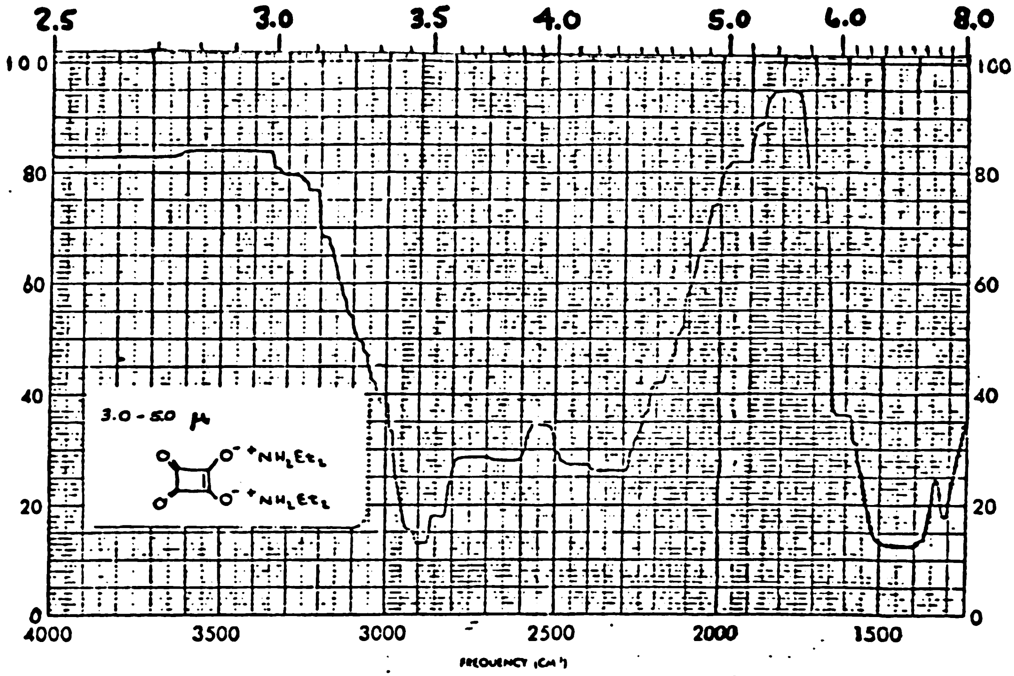
SAMPLE CH3/CH2 = 3/2 [illegible]
ACTUAL = 3.04/2

SOLVENT

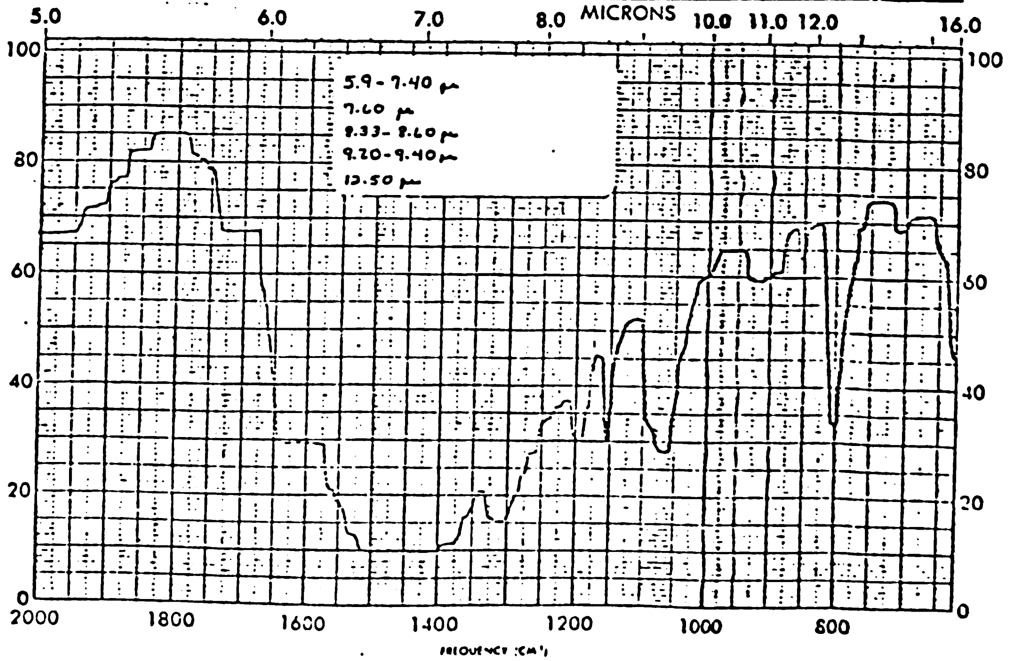
DATE 9-12-79

OPERATOR KF

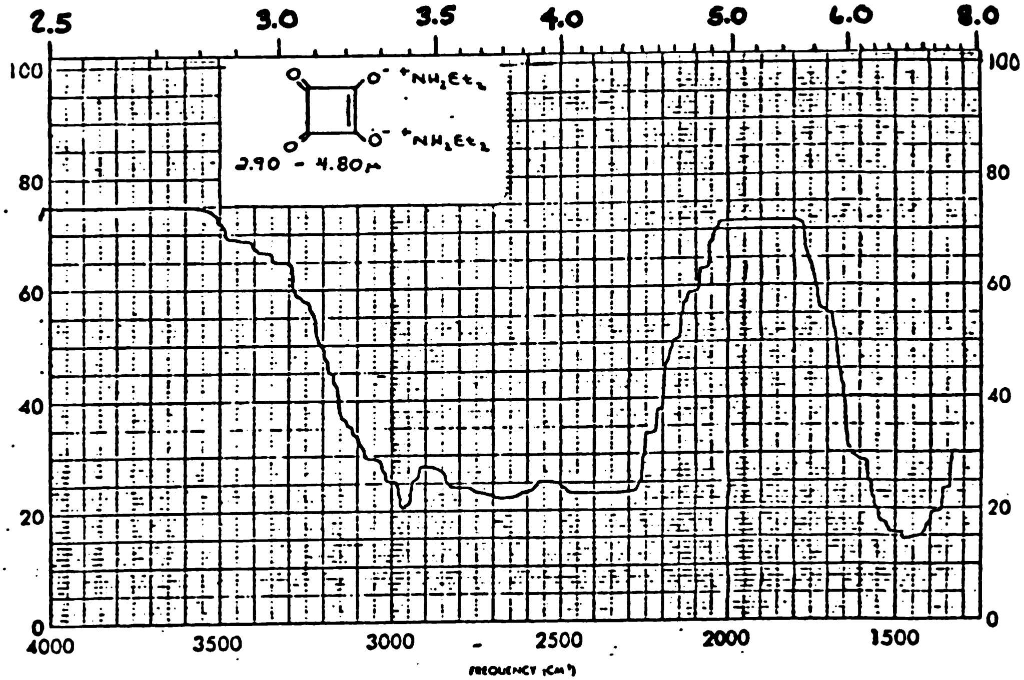
SPECTRUM NO. 26



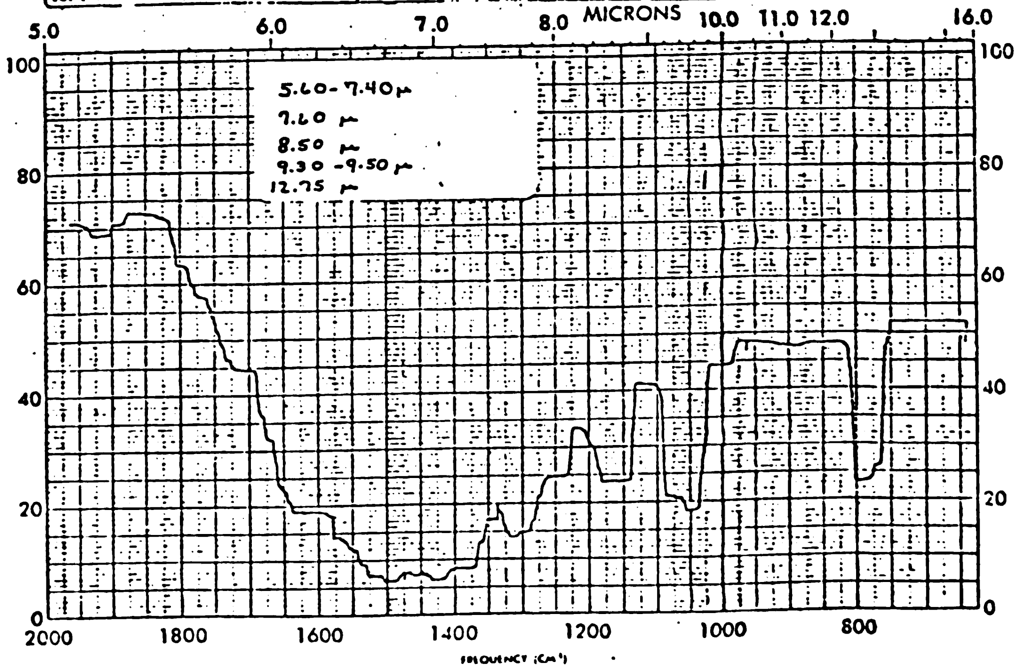
SAMPLE 26	CURVE NO. —	SCAN SPEED Slow	OPERATOR FEY
	CONC —	SLIT N	DATE 3-13-79
ORIGIN —	CELL PATH —	REMARKS	
	REFERENCE —		



SAMPLE 26	CURVE NO. —	SCAN SPEED Slow	OPERATOR FEY
	CONC —	SLIT N	DATE 3-13-79
ORIGIN —	CELL PATH —	REMARKS	
SOLVENT Nujol	REFERENCE —		



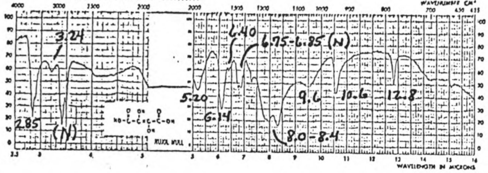
SAMPLE 26	CURVE NO. —	SCAN SPEED Slow	OPERATOR EF
	CONC. —	SLIT 6	DATE 3-12-79
ORIGIN —	CELL PATH —	REMARKS	
SOLVENT KBR	REFERENCE —		



SAMPLE 26	CURVE NO. —	SCAN SPEED Slow	OPERATOR KF
	CONC. —	SLIT 6	DATE 3-12-79
ORIGIN —	CELL PATH —	REMARKS	
SOLVENT KBr	REFERENCE —		

REFERENCE : ALDRICH IR CATALOG

D11,320-4 Dihydroxymaleic acid (dihydroxyfumaric acid), see J. Am. Chem. Soc. 75, 6244 (1953)
$HO_2CC(OH){:}C(OH)CO_2H$ M.W. 148.07
m.p. 156° (dec.) ....



COMPOUND 29 , NUJOL