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The synthesis of primary o-substituted hydroxylamines for the study of nucleophilic substitution at the electrophilic nitrogen center

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The Synthesis of Primary, O-Substituted Hydroxylamines for the Study Of Nucleophilic Substitution at the Electrophilic Nitrogen Center

by

Richard M. Sommer

Submitted in partial fulfillment
of the requirements for
Honors in the Departments of Chemistry and Biology

UNION COLLEGE

March, 1975

This thesis

is

Submitted by

Richard M. Sommer

to the Departments of Chemistry and

Biology of Union College

in partial fulfillment of the requirements for

Honors

Leslie A. Hull

ABSTRACT

SOMMER, RICHARD M. The synthesis of primary, O-substituted hydroxylamines for the study of nucleophilic substitution at the electrophilic nitrogen center. Departments of Chemistry and Biology, March 1975.

Within the past fifteen years bimolecular nucleophilic substitution reactions at the sp^3 hybridized nitrogen center have been the topic of some investigation. The synthesis of O-substituted hydroxylamines was undertaken in order to obtain substrates for the study of these substitution reactions.

Mesitylenesulfonyl chloride and t-butyl N-hydroxycarbamate were reacted to form the N-blocked t-butyl N-mesitylenesulfonyloxycarbamate. Subsequent acid cleavage of the nitrogen blocking group with trifluoroacetic acid yielded O-mesitylenesulfonylhydroxylamine. Unsuccessful kinetic studies of the reaction of iodide with O-mesitylenesulfonylhydroxylamine are reported. Attempts to synthesize O-(2,4-dinitrophenyl)hydroxylamine utilizing t-butyl N-hydroxycarbamate and ethyl acetohydroxamate as sources of N-blocked hydroxylamine failed. In both cases the source of the 2,4-dinitrophenyl group was 2,4-dinitro-1-chlorobenzene. It is thought O-(2,4-dinitrophenyl)hydroxylamine is unstable under the acidic conditions in which it is formed.

Model studies of the S_N2 reaction of hydroxylamine

and sodium methoxide with α-p-dichlorotoluene were performed to determine the optimal conditions for the synthesis of O-(p-chlorobenzyl)hydroxylamine. The desired product was best synthesized by reacting five equivalents of hydroxylamine with one equivalent of α-p-dichlorotoluene in the presence of 0.66 equivalents of sodium methoxide. It is thought these conditions can be extended to the S_NAr synthesis of O-(2-nitrophenyl)hydroxylamine from 2-nitro-1-chlorobenzene, hydroxylamine and sodium methoxide.

To my parents

ACKNOWLEDGMENT

Acknowledgment is made to the donors of the Petroleum Research Fund, administered by the American Chemical Society, for partial support of this research.

I would like to thank Dr. Leslie A. Hull for his advice, assistance and guidance during the course of this research.

"Just as the male-female polarity makes the world go round, so the mating of nucleophiles and electrophiles is responsible for a good deal of activity on the molecular level."

Stephen J. Weininger, Contemporary Organic Chemistry.

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INTRODUCTION

The sp^3 hybridized carbon has been, for the past 30 years, the subject of intensive study with respect to nucleophilic substitution reactions. Complete studies of the nucleophilic character of nucleophiles, character of leaving groups and the effects of solvent on the rate of reaction have been investigated. This has not, however, been the case with respect to nucleophilic attack on the sp^3 hybridized nitrogen. In fact only within the last few years have truly intensive studies been reported.

In 1959 Collier, Jr. et al.[1] reported the rate of hydrazine formation from the reaction of chloramine and ammonia in liquid ammonia to follow pseudo-first order kinetics. Braude et al.[2] in 1961 found that the reaction of chloramine with triethylamine proceeded in second order overall and first order in each of these reactants. These results could, therefore, be interpreted as the reaction occurring via an S_N2 mechanism. Yagil et al.[3] in 1962 reported the rate of formation of hydrazine from the same two reactants in aqueous solution to proceed by second order kinetics, i.e. first order in each reactant. Anbar et al.[4] reported that same year that the hydrolysis of chloramine in alkaline solution was first order in chloramine and had a linear dependence on the H_- acidity function. Each of these studies was consistent with S_N2 attack of the nucleophile on the sp^3 hybridized nitrogen with subsequent loss of the chloride. For an example we can take the attack

of hydroxide on the sp^3 hybridized nitrogen in chloramine.

$$OH^{\ominus} + NH_2Cl \xrightarrow{S_N2} HONH_2 + Cl^{\ominus}$$

Sisler et al.[5] in 1959 showed that hydroxylamine-O-sulfonic acid could be employed as an aminating reagent. The technique was essentially a synthetic one, but this reagent would later be utilized in an extensive study of S_N2 reactions at the nitrogen center.

The reaction of hydroxylamine-O-sulfonic acid with water and hydriodic acid was kinetically studied by Smith et al.[6] in 1964. They concluded that S_N2 attack of I^- on nitrogen with simultaneous leaving of the sulfonate anion occurred. Steric affects were noted since the rate of reaction was slowed if the nitrogen was substituted with methyl groups. The reaction with water, however, was determined to take place via nucleophilic attack on the sulfur.

In 1966 le Noble[7] reported results he had obtained when studying the displacement of chloride from chloramine via the attack of hydroxide ion. His results reconfirmed the S_N2 character of the reaction as had been reported earlier. However, his results indicated alkyl substitution of chloramine had little effect on the reaction rate.

Yap et al.[8] in 1967 reported on the kinetic study which they had conducted with respect to the reaction of various anions with difluoramine. Their results, too, implied an S_N2

mechanism with the order of reactivity for the various anions being given as follows:

$$OH^{\ominus} > HSO_3^{\ominus} > CN^{\ominus} > I^{\ominus} > SCN^{\ominus} > N_3^{\ominus} > Br^{\ominus} > Cl^{\ominus} > H_2PO_4^{\ominus} > {}^{\ominus}OAc.$$

This ranking correlated well with the nucleophilicity of these reagents with respect to sp^3 hybridized carbon, the only exception being hydroxide. It was implied that hydroxide might have been reacting via a different mechanism.

Synthetic work by Sheradsky[9] in 1968 indicated that O-(2,4-dinitrophenyl)hydroxylamine could be utilized as an aminating reagent. Although kinetic studies were not performed it was assumed that this reaction too proceeded with nucleophilic attack on the amine nitrogen with simultaneous leaving of the 2,4-dinitrophenolate anion. In 1972 Tamura et al.[10,11] reported the use of O-mesitylenesulfonylhydroxylamine as an effective aminating reagent.

Oae et al.[12] (1973) reported the first kinetic studies of nucleophilic substitution at nitrogen of O-(2,4-dinitrophenyl) hydroxylamine. The limited results indicated displacement took place via an S_N2 mechanism. Steric factors with regard to the nucleophile were reportedly minimal presumably because the lone electron pair of nitrogen was more easily distorted than the bonds about sp^3 hybridized carbon atoms. The rate constants which were derived for these reactions were similar to the nucleophilic order of the reagents utilized. These reagents included pyridine, α-picoline, 2,6-lutidine, triphenylphosphine and methyl phenyl sulfide.

The most important work with regard to nucleophilic reactions at the sp^3 hybridized nitrogen has been reported within the last year. Krueger et al.[13] (1973) confirmed once again the S_N2 character of the reaction of nucleophiles with hydroxylamine-O-sulfonate anion. The nucleophiles employed were, in order of decreasing nucleophilicity, $(C_6H_5)_3 P > I^{\ominus} > (C_2H_5)_3 N >> Br^{\ominus}, Cl^{\ominus}$. Protonation of the nitrogen decreased the observed reaction rate. Substitution of methyl groups at the nitrogen also slowed the rate of reaction which implied a large steric influence in the transition state. Krueger et al.[14] (1975) extended this study and added thiosulfate and thiourea to the list of nucleophiles. Krueger et al.[15] (1974) studied this same reaction utilizing iodide and triphenylphosphine in dimethyl sulfoxide-water solvents of various mole fraction. Their results indicated decreasing rate constants as the mole fraction of DMSO was increased from 0 to 1. It was suggested that in the case of $\overset{\oplus}{N}H_3OSO_3^{\ominus}$ the proton is found on the nitrogen making the leaving group SO_4^{2-}. SO_4^{2-} is better stabilized in water than in DMSO which would account for the decreased reactivity as the mole fraction of DMSO is increased.

Krueger et al.[16] (1974) added to the list of nucleophiles studied ethanethiolate, hydroxylamine and hydroxide and correlated these results with those already obtained. The results of these reactions proved S_N2 kinetics in each case. The order of nucleophilicity was established as:

$(C_2H_5S^{\ominus}) \approx (C_6H_5)_3\ P > (H_2N)_2\ CS > {}^{\ominus}O_3SS^{\ominus} > I^{\ominus} > (Br^{\ominus} > Cl^{\ominus}) > (C_2H_5)_3N > HONH_2 > OH^{\ominus}$ in which the reactivity range was 10^6. The order is qualitatively parallel to that established for sp^3 hybridized carbon and suggests that in substitution at sp^3 hybridized nitrogen of compounds of the type NH_2-X polarizability of the nucleophile plays a major role while basisity makes a minor contribution.

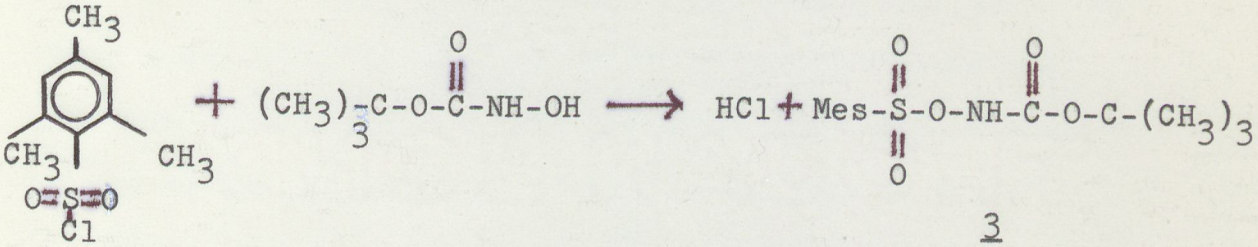
The purpose of this work is to synthesize primary O-substituted hydroxylamines which would be useful in studying the kinetics of S_N2 reactions at the electrophilic nitrogen center.

The technique which Krueger et al.[13] reported for following the reaction of iodide with hydroxylamine-O-sulfonate was to follow the production of $I_3^{\ominus}$ spectrophotometrically by measuring the absorbance at 400 nm. The stoichiometry for that reaction is as follows:

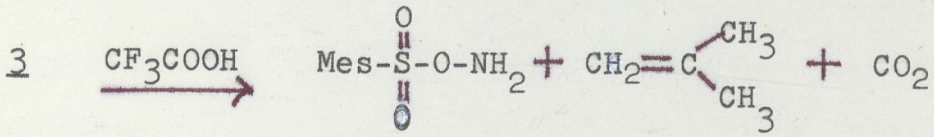
$$H_2N - OSO_3^{\ominus} + 3I^{\ominus} + 2H^{\oplus} \longrightarrow I_3^{\ominus} + NH_4 + SO_4^{2-}$$

Additional spectrophotometric and titrametric techniques for following the reaction of hydroxylamine-O-sulfonate with triphenylphosine and triethylamine were also provided in the Krueger paper. With these techniques available it was thought that O-mesitylenesulfonylhydroxylamine could be synthesized and its reaction with iodide followed in a manner similar to that given above. Krause[17], Carpino[18], and Tamura et al.,[19] each reported procedures for the synthesis of

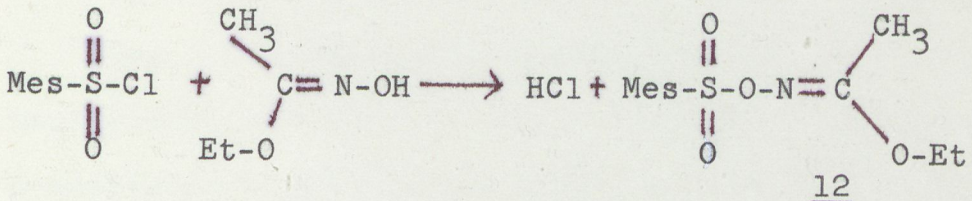
O-mesitylenesulfonylhydroxylamine. The first two methods utilized mesitylenesulfonylchloride and t-butyl N-hydroxy-carbamate which is an N blocked form of hydroxylamine. Cleavage of the blocking group was accomplished by placing

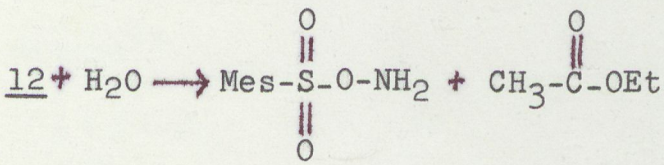


the t-butyl N-mesitylenesulfonyloxycarbamate in trifluoro-acetic acid. The method which Tamura et al.[19] reported relies upon ethyl acetohydroxamate as the N blocked form of



hydroxylamine. Ethyl-O-mesitylene sulfonylacetohydroxamate was prepared and the blocking group was cleaved by adding the elements of water across the N=C bond in an acid catalyzed reaction.

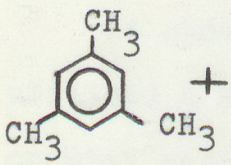




DISCUSSION

A. O-MESITYLENESULFONYLHYDROXYLAMINE

O-Mesitylenesulfonylhydroxylamine was successfully prepared via a four step procedure which began with mesitylene, chlorosulfonic acid and hydroxylamine hydrochloride. The first step involved the synthesis of mesitylenesulfonyl chloride from mesitylene and chlorosulfonic acid according to the method of Huntress et al.[20] and Wang et al.[21]



$$+ \quad 2ClSO_3H \longrightarrow Mes\text{-}S(=O)_2\text{-}Cl \; (\underline{1}) + HCl + H_2SO_4$$

An N-blocked derivative of hydroxylamine, t-butyl N-hydroxycarbamate, was prepared by reacting hydroxylamine hydrochloride with t-butylazidoformate in the presence of base according to the procedure given by Carpino et al.[22]

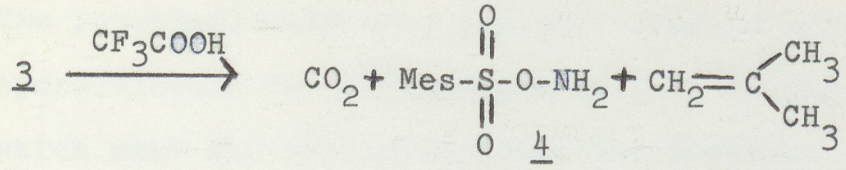
$$(CH_3)_3\text{-}C\text{-}O\text{-}C(=O)\text{-}N_3 + \overset{\oplus}{N}H_3OH \; \overset{\ominus}{Cl} + 2NaOH \longrightarrow$$

$$(CH_3)_3C\text{-}O\text{-}C(=O)\text{-}NHOH \; (\underline{2}) + 2H_2O + 2\overset{\oplus}{N}a + \overset{\ominus}{Cl} + \overset{\ominus}{N}_3$$

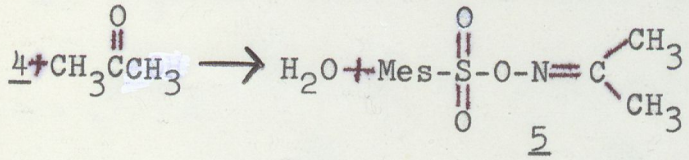
The N-blocked hydroxylamine was then reacted with mesitylenesulfonyl chloride and base to produce t-butyl N-mesitylenesulfonyloxycarbamate according to the method of Krause[17].

$$\underline{1} + \underline{2} + Et_3N \longrightarrow \overset{\oplus}{Et_3}\overset{\ominus}{NHCl} + Mes\text{-}S(=O)_2\text{-}O\text{-}NH\text{-}C(=O)\text{-}O\text{-}C\text{-}(CH_3)_3 \; (\underline{3})$$

The blocking group was then cleaved by reaction of $\underline{3}$ with trifluoroacetic acid[17]. In order to chemically prove

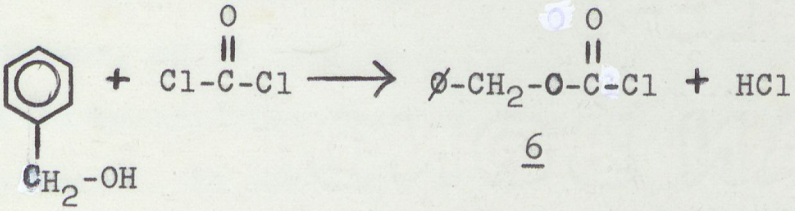


the structure of 4 mesitylenesulfonylacetoxime was prepared by reacting 4 with acetone[18].

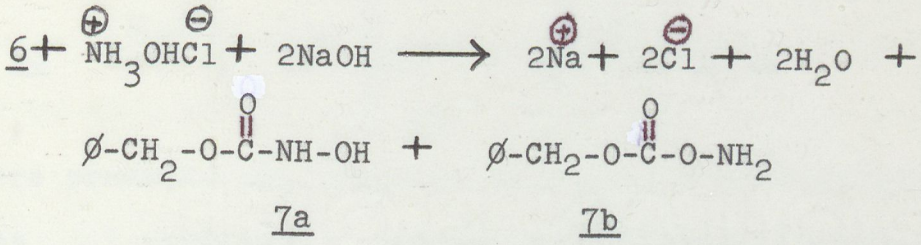


It should be noted that this synthetic procedure utilized a nitrogen blocking group the same way a peptide chemist would use such a group if he were trying to synthesize a polypeptide from simple amino acids. Due to the ambident nucleophilic character of the hydroxylamine molecule it was thought that if it were reacted with mesitylenesulfonyl chloride under the conditions given above the predominant, and probably only, product would have been the N-mesitylenesulfonylhydroxylamine.

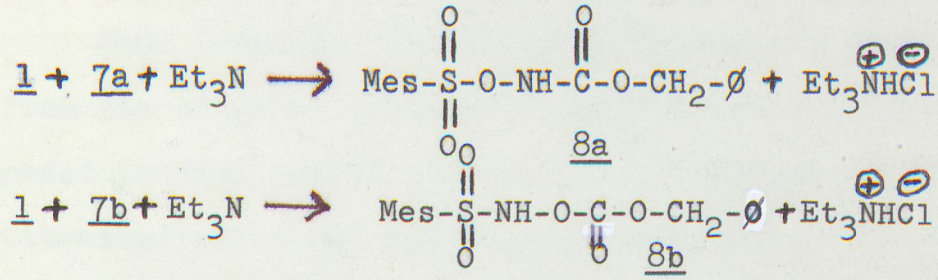
Another synthetic procedure was employed in order to obtain O-mesitylenesulfonylhydroxylamine. This method involved the use of benzylchloroformate as the blocking group instead of the more expensive t-butylazidoformate. Benzylchloroformate was synthesized according to a modified method of Carter et al.[23] by reacting benzyl alcohol with phosgene.



The benzylchloroformate was next reacted with hydroxylamine hydrochloride in the presence of base to yield two products which were not separated after the reaction. At the time

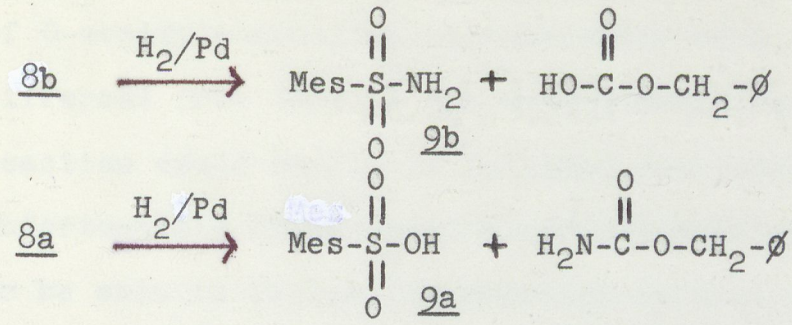


this reaction was run it was not certain that the O-blocked hydroxylamine was present, but its presence was suspected. The mixture of O- and N-blocked hydroxylamine was reacted with mesitylenesulfonylchloride in the presence of base to yield two products. It was originally thought that by

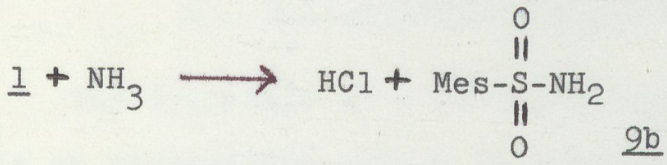


hydrogenating these products over a palladium catalyst the blocking group could be cleaved leaving behind a mixture of O-mesitylenesulfonylhydroxylamine and N-mesitylenesulfonyl-hydroxylamine. While the cleavage reaction was running the thought occurred that the bond most likely broken would be the weak N-O bond rather than the O-C or N-C bond. This was, however, not a total loss because the product of this reaction could be utilized to provide information about the starting material. If mesitylenesulfonamide were produced the starting material was O-blocked hydroxylamine. On the other

hand if mesitylenesulfonic acid



were produced the presence of benzyl N-hydroxycarbamate was confirmed. Genuine mesitylenesulfonamide was synthesized by reacting mesitylenesulfonyl chloride with ammonia in water solution. Both 9a and 9b were produced by the cleavage.

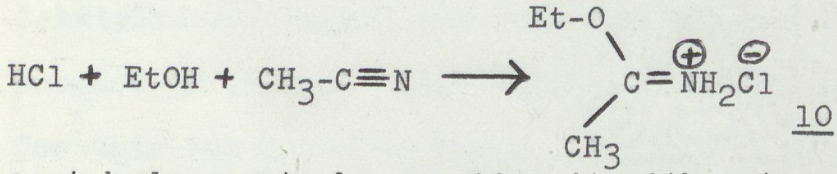


Some O-mesitylenesulfonylhydroxylamine was available from the original synthesis and it became appropriate to react it with iodide and follow the kinetics of the reaction titrametrically and spectrophotometrically. As indicated (see intro.) the method involved observing changes with regard to I_2 and I_3^-, not the mesitylenesulfonate group. The results were erratic. The problem with following the reaction in this matter was that any type of side reaction which might be occurring, such as air oxidation of I^- to I_2, would introduce an error into the experiment which, if left uncorrected, would make the results impossible to interpret. In our case it appeared as if the reaction were so slow that air oxidation interfered significantly with following the reaction. The best way of following the reaction would be

to observe changes in the leaving group. If the UV spectrum of O-mesitylenesulfonylhydroxylamine were significantly different from that of the mesitylenesulfonate anion, the reaction could easily be followed spectrophotometrically. Unfortunately these spectra are not sufficiently different to be able to follow the reaction in that way. However, a molecule which would yield an anion of significantly different UV spectrum than its O-hydroxylamine was O-(2,4-dinitrophenyl)hydroxylamine.

B. O-(2,4-DINITROPHENYL)HYDROXYLAMINE

The synthesis of O-(2,4-dinitrophenyl)hydroxylamine via an inexpensive method reported by Tamura et al.[19] was attempted. The blocking group, ethyl acetohydroxamate, was synthesized according to procedures given by Migridichian[24] and Houben et al.[25] First, acetimino ethyl ether hydrochloride was synthesized from acetonitrile, ethanol and hydrogen chloride. This material was converted to ethyl



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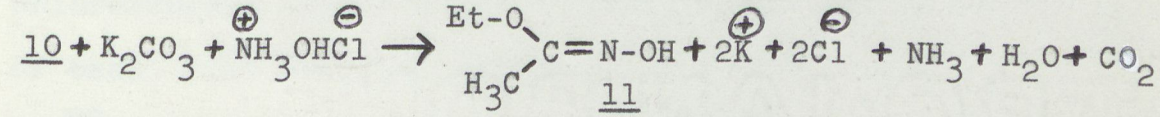
acetohydroxamate by reacting it with potassium carbonate and hydroxylamine hydrochloride. By reacting ethyl aceto-



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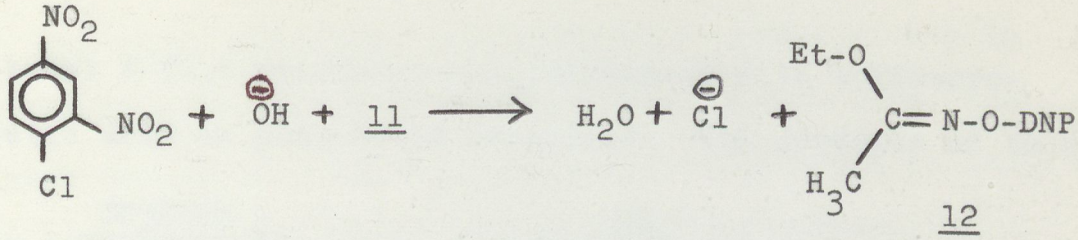
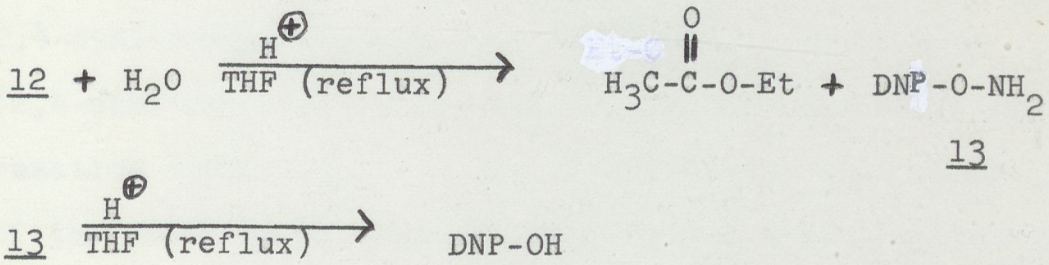
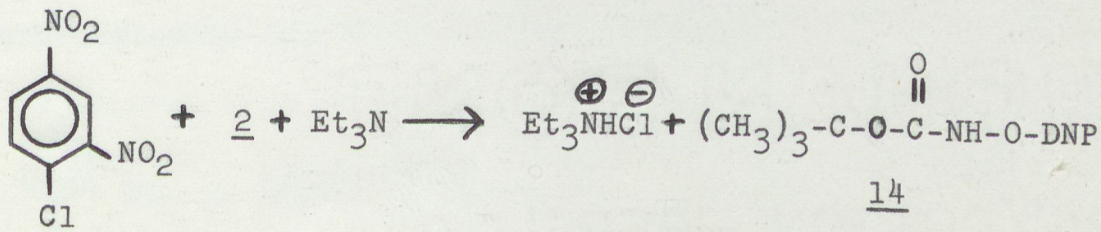
hydroxamate with 2,4-dinitro-1-chlorobenzene in the presence of base ethyl-O-(2,4-dinitrophenyl)acetohydroxamate could be formed. The next step in this reaction sequence is, according



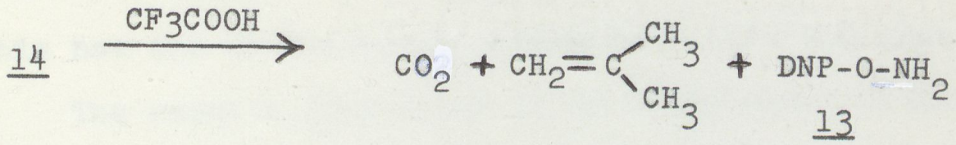
to Tamura[19], the acid catalyzed cleavage of the blocking group using 70% perchloric acid in dioxane solvent. It was found that at 0°C no reaction occurred. The conditions were extended to 70% perchloric acid in tetrahydrofuran solvent at reflux. It was clear that under these conditions a reaction had occurred. However, the product formed under these vigorous conditions was most likely 2,4-dinitrophenol.



Even though this procedure proved unsuccessful it was thought that if a different blocking group were used, perhaps t-butylazidoformate, the reaction might proceed and yield the product of choice. The method of Sheradsky[26] was employed for this synthetic sequence. t-Butyl N-(2,4-dinitrophenoxy)carbamate was produced by reacting 2,4-dinitro-1-chlorobenzene with t-butyl N-hydroxycarbamate in the presence of base. The blocking group was cleaved by reacting



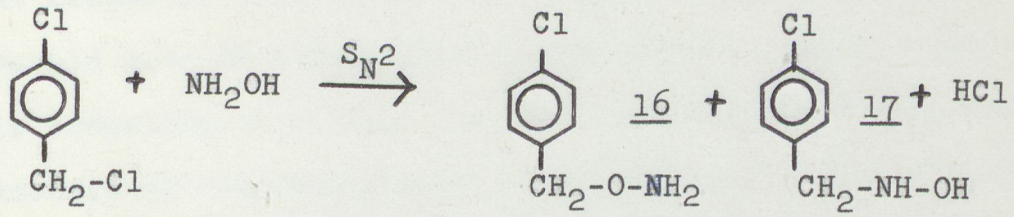
t-butyl N-(2,4-dinitrophenoxy)carbamate with trifluoroacetic acid as previously described. The products of this



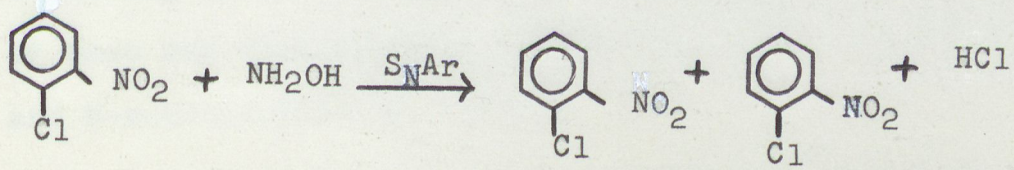
reaction were just as difficult to isolate as those of the methods which employed the ethyl acetohydroxamate group.

C. MODEL STUDIES WITH BENZYL HALIDES

It was thought that the synthetic procedures with the 2,4-dinitrophenyl group were unsuccessful because O-(2,4-dinitrophenyl)hydroxylamine was unstable under the reaction conditions. It was at this point that model studies of the reaction of hydroxylamine with ∝-p-dichlorotoluene were undertaken in the hope that the conditions for the formation of O-(p-chlorobenzyl)hydroxylamine could be elucidated. It



was thought that if these S_N2 conditions could be optimized they could be applied to an S_NAr mechanism of interest such as the formation of O-(o-nitrophenyl)hydroxylamine from hydroxylamine and 2-nitro-1-chlorobenzene.



The major advantage this synthetic method offers is that no blocking group is employed which means that from primary reactants to final products only one step is involved. This has the advantage of saving both time and money.

The results (see table 1) of these model studies indicated that O-hydroxylamine substitution could be best facilitated by maintaining an excess of base throughout most of the reaction. Hydroxylamine is an ambident nucleophile. In neutral solutions the nitrogen end is more nucleophilic because the unshared electrons in the sp^3 orbital will readily attack the α-carbon of α-p-dichlorotoluene. In basic solutions an equilibrium between the base and the hydroxylamine exists with regard to the proton bonded to the

$$NH_2OH + CH_3O^{\ominus} \longrightarrow CH_3OH + NH_2O^{\ominus}$$

hydroxylamine oxygen. The negatively charged hydroxylamine oxygen is significantly more nucleophilic than the neutrally charged nitrogen of hydroxylamine, and in a solution where an excess of base is present O-substitution is favored. It should also be noted that in the alcohol solvent NH_2O^- is competing with CH_3O^- so that in order to obtain significant amounts of O-hydroxylamine substituted products the NH_2OH concentration must be as high as possible.

It should be noted that during the course of the reaction of hydroxylamine with α-p-dichlorotoluene, hydrogen chloride is released. If only a small excess of base is present at the beginning of the reaction, to wit, less than equimolar amounts of base and electrophile, the solution quickly becomes acidic and N-substitution is favored.

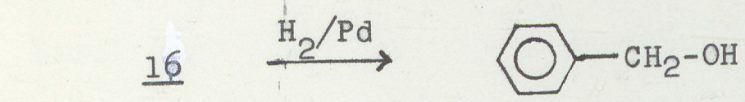
TABLE I

Summary of Model Studies

Run	$[NH_2OH]$	$[CH_3\bar{O}]$	[α-p-Dichlorotoluene]	%16	%17
1	0.5 M	0.065 M	0.5 M	0	100
2	0.67	0.087	0.33	56	44
3	1.0	0.13	0.2	52	48
4	2.5	0.33	0.5	100	0

The various amounts of p-chlorobenzyl methyl ether reported in the preduct mixture of each reaction are not significant because they are merely an indication of how well the separation technique worked. The acid extractions which were performed during the workup were designed to leave behind such neutral species as starting material and ethers. The fact that varying amounts of O-methyl ether were found clearly indicates its formation as a by-product and that the separation technique was, at times, sloppy.

The O-(p-chlorobenzyl)hydroxylamine product was chemically proven by hydrogenating it over a palladium catalyst yielding



p-chlorobenzyl alcohol. p-Chlorobenzyl alcohol was independently synthesized by reacting ∝-p-dichlorotoluene with sodium hydroxide yielding the desired product. The proof was made by comparing the NMR spectra of the products of both reactions.

The reaction of mesitylenesulfonyl chloride with hydroxylamine and sodium methoxide yielded, exclusively N-mesitylenesulfonylhydroxylamine. What may have occurred in this case was the initial reaction of hydroxylamine anion with mesitylenesulfonyl chloride. However, after the excess base was used up hydroxylamine may have begun reacting with the O-mesitylenesulfonylhydroxylamine via attack at sulfur and displaced the O-substituted hydroxylamine thus yielding the N-substituted product. The fact that the reaction was performed for seven days adds validity to this theory since one would expect the thermodynamic product to be favored in such a case.

RESULTS

I. EXPERIMENTAL

A. O-Mesitylenesulfonylhydroxylamine

1. Mesitylenesulfonyl chloride: In a 500 ml round bottom flask were placed 50.4 g (0.42 mol) of mesitylene and 200 ml of chloroform. The flask was cooled to 0°C and 130 ml of chlorosulfonic acid were slowly added over a 30 minute period. A reflux condenser was attached to the flask to prevent loss of product. Once all of the acid had been added the reaction mixture was heated to reflux for 30 minutes. When the reaction was complete the mixture was carefully poured over ice and the aqueous layer separated from the organic layer. The chloroform was removed by distillation. The melted product was added to ligroin (63-75°C.) and heated to boiling. The solution was decolorized with charcoal and recrystallization from ligroin completed. To achieve a relatively pure product three recrystallizations were required. Product: 7.15 g, 7.7% of 1; mp. 54-56°C. ref.[20] 53-56. White to light brown crystalline plates.

1. Mesitylenesulfonyl chloride: To 200 ml of chloroform were added 50.4 g (0.420 mol) of mesitylene. The mixture was cooled to 0°C and 232 g (2.0 mol) of chlorosulfonic acid were added at a rate of 1 drop/2.6 s. The mixture was stirred vigorously throughout the entire addition process. The aqueous layer was separated from the organic layer and the chloroform

was removed at the rotavap leaving behind crystals which were dissolved in ligroin, decolorized and recrystallized once. Yield; 83.5 g, 92%, m.p. 47-52.5°C., ref.[20] 53-56°C.

2. t-Butyl N-hydroxycarbamate: 13 g (0.19 mol) of hydroxylamine hydrochloride were added to 40 ml of water and placed in a 500 ml round bottom flask. To this solution were added 20 ml (0.14 mol) of t-butylazidoformate (commercial, Aldrich). A cold solution containing 22.4 g (0.56 mol) of sodium hydroxide in 80 ml of water was added to the continuously stirred reaction mixture over a one hour period. Once the addition had been completed extractions of the reaction mixture with two 50 ml portions of ether were accomplished. These extracts were discarded. The aqueous solution was acidified with 40 ml of 12 M hydrochloric acid and extracted five times with 40 ml ether portions. The extracts were dried over calcium chloride and the ether was removed by evaporation. An oil formed which solidified and was dissolved in hot ligroin (63-75°C.). The solution was cooled and the crystals which formed were filtered on a Buchner funnel. Product: 13.7 g, 72%; mp. 55-57°C., ref.[22] 56-58°C; white crystals.

3. t-Butyl N-mesitylenesulfonyloxycarbamate: In a 500 ml round bottom flask were placed 5.45 g (0.025 mol) of mesitylenesulfonyl chloride and 3.32 g (0.025 mol) of t-butyl N-hydroxycarbamate. 100 ml of ether were added to dissolve the reactants. Triethylamine, 2.56 g (0.025 mol), was added

dropwise with stirring at 0°C. over a 45 minute period. After the reaction was complete the mixture was filtered and the triethylamine hydrochloride crystals were washed twice with 50 ml ether portions. The filtrate was allowed to evaporate for three days to remove all the ether. The crystals were dissolved in 10 ml of warm benzene and precipitated with the addition of 20 ml of petroleum ether. The precipitated crystals were filtered and dried. Product: 6.4 g; 81%; mp. 92-102°C. and the mixture had not completely melted, ref.[17] 102-104°C. White crystalline product.

3. t-Butyl N-mesitylenesulfonyloxycarbamate: In 100 ml of ether were placed 19.4 g (0.089 mol) of 4 and 11.8 g (0.089 mol) of t-butyl N-hydroxycarbamate. To the mixture were slowly added 9.0 g (0.089 mol) of triethylamine. The reaction appeared to preceed well with triethylamine hydrochloride precipitate being found at the bottom of the flask. The precipitate was trapped on a piece of filter paper and the filtrate placed in a flask. The filtrate was then placed on a hotplate in order to remove the ether. Unfortunately all of the ether was removed and the temperature reached a level high enough to detonate the product.

4. O-Mesitylenesulfonylhydroxylamine: To 4 g (0.013 mol) of impure t-butyl N-mesitylenesulfonyloxycarbamate were added 15 ml of trifluoroacetic acid which had been purified by distillation. The mixture was stirred for 5 minutes and the product poured into 100 ml of ice water. The precipitate

was filtered and dissolved in 10 ml of ether. 40 ml of petroleum ether were added to the mixture to precipitate the product. Product: 2.4 g; 88%; at 83°C. the product decomposed, ref.[18] 80°C. d. White, feathery crystals.

5. O-Mesitylenesulfonylacetoxime: This acetoxime was prepared by reacting 3 ml of acetone with a few tenths of a gram of 4. The product was crystallized on addition of water and filtered. The product was dissolved in benzene and recrystallized with the addition of ligroin. Product: mp. 95.0-96.5°C., ref.[18] 95.0-96.5°C. White crystals.

6. Benzylchloroformate: Phosgene, 24.4 g (0.247 mol), in benzene solution (M.C.B.) was placed in flask along with 24.5 g (0.227 mol) of benzyl alcohol. The reactants were allowed to react at 0°C for 30 min. at room temperature for 2 hours. A vacuum distillation was performed (23°, 52 torr. and 28°, 70 torr.) to remove some of the benzene and all of the unreacted phosgene. 90% reaction with respect to benzyl alcohol was assumed for the succeeding steps.

7a. Benzyl N-hydroxycarbamate: Hydroxylamine hydrochloride, 14.2 g (0.204 mol), and sodium hydroxide, 8.15 g (0.204 mol), were dissolved in 40 ml of water. The solution was cooled to 0°. Simultaneously approximately equimolar amounts of carbobenzoxychloride, 34.8 g (0.204 mol), in benzene solution and 8.15 g (0.204 mol) of sodium hydroxide in aqueous solution were slowly added to the reaction mixture. Once the reaction was complete the aqueous layer was separated

from the organic layer and extracted twice with 50 ml portions of benzene. The extracts were dried over calcium chloride and evaporated at the rotavap. Yield; 29.6 g, 87% of crude product. Recrystallization from benzene-ligroin gave crystals with an m.p. of 50°-60°, ref.[28] 71°. It was later confirmed that approximately half of this product was 7b.

8a and 8b: 7a and 7b, 14.7 g (0.089 mol), were dissolved in ether along with 19.4 g (0.089 mol) of 1. 9.0 g (0.089 mol) of triethylamine were slowly added to the stirred mixture at 0°. After an hour of reaction the mixture was filtered and the precipitate washed twice with ether. The ether was evaporated from the filtrate to yield 32.2 g, 104% of crude product. m.p. 109-113°. Recrystallized from ethanol, m.p. 114-116.5°.

9a and 9b: 8a and 8b, 1g (2.9×10^{-3} mol), were placed in 10 ml of methanol along with 0.1 g (5.7×10^{-4} mol) of palladium chloride. A hydrogen balloon was placed over the flask and the cleavage accomplished. Yield; 0.25 g (40%) of product which had been extracted with ether and the ether evaporated at the rotavap. m.p. 123-138°., ref.[29] for 9b 141-142°.

9b: 0.4 g (1.8×10^{-3} mol) of 1 were placed in a test tube containing 7 ml of 28% ammonium hydroxide. The tube was heated to boiling and the product was acidified with hydrochloric acid. The product was dissolved in ethanol, filtered hot and recrystallized. Yield; unweighable amount,

mp. 141.5-3.0°, ref.[29] 141-2.

B. Synthesis of O-(2,4-Dinitrophenyl)hydroxylamine

10. Acetimino ethyl ether hydrochloride: The procedure of Migrdichian[24] was followed for this reaction. 78.56 g (1.91 mol) of acetonitrile and 88 g (1.91 mol) of ethanol were placed together in a flask. HCl gas was introduced to the flask from a tank nearby. The reaction was permitted to proceed for several days. Workup involved the removal of some unreacted solvent at the rotavap and the eventual addition of benzene to remove all of the solvent at the end of the evaporation. Yield; 55.2 g, 20.7% of white crystals. No melting point was determined.

11. Ethyl acetohydroxmate: 50 g (0.43 mol) of 10 were placed in aqueous potassium carbonate, 110 g (0.80 mol). Acetimino ethyl ether was separated and the aqueous solution extracted with ether. The ether extracts and the acetimino ethyl ether were added to a saturated aqueous solution of hydroxylamine hydrochloride. The ether layer was separated and two 50 ml ether extractions of the aqueous layer were made. All ether layers were combined, dried over calcium chloride and evaporated at the rotavap. Yield; 25.3 g, 68%.

12. Ethyl-O-(2,4-dinitrophenylacetohydroxamate: The procedure of Ilvespää[27] was utilized in this reaction. In 150 ml of ethanol were dissolved 9.83 g (4.85×10^{-2} mol) of 2,4-dinitrochloro benzene. In a separate 75 ml ethanol

solution were dissolved 5 g (4.85×10^{-2} mol) of potassium hydroxide. The 150 ml solution was slowly added to the ethyl acetohydroxamate solution at 0° with stirring. The mixture was allowed to stand for an additional 45 minutes after the reaction was complete. A precipitate of product formed which was filtered and washed first with ethanol and then with water. Yield; 10.3 g, 79%, m.p. 108-111°, ref[27] 111-112.

13. O-(2,4-dinitrophenyl)hydroxylamine: The following reaction essentially extends the conditions which Tamura[19] utilized in his work. In tetrahydrofuran, 4.6 ml, were dissolved 1g (0.0037 mol) of 9a and 3 ml of 70% perchloric acid. The reaction mixture was heated to reflux and held there for 30 to 60 minutes. It was then poured into ice water and the precipitate was isolated. This reaction was attempted under less vigorous conditions and the cleavage was essentially not accomplished. The crude product was isolated and weighed. Yield; 0.5 g, 68%. The problem has been in purifying the product mixture which includes 2,4-dinitrophenol.

Various recrystallization techniques involving ethanol, ethyl acetate-ethanol, and ethyl acetate-hexane have been unsuccessful in isolating a pure sample of the product. Recent attempts involving column chromatography have been made. However the results of this work were not encouraging. The column utilized in this work was a 10 cm alumina column with methanol solvent. Samples have been chromatographed which gave pure

(TLC analysis) products but they could not be positively identified.

14. t-Butyl N-(2,4-dinitrophenoxy)carbamate: The method of Sheradsky[26] was utilized in this synthesis. To 80 ml of ethanol were added 4.0 g (0.20 mol) of 2,4-dinitro-1-chlorobenzene. This solution was slowly added to a 45 ml ethanol solution of 2.6 g (0.02 mol) t-butyl N-hydroxy-carbamate and 1.1 g (0.02 mol) of potassium hydroxide. The reaction was run for 3/4 hour more than it took to add all of the 80 ml of ethanol solution. Acetic acid was added to the solution until it changed color to light yellow. Next the mixture was poured into water and stored. Gentle stirring of the ice cold solution caused the oil which had formed to solidify. The crude product was recrystallized from ethyl acetate-hexane. Light yellow needles had formed after some solvent had been removed at the rotavap. m.p. 95-97°, ref.[26] 74-5. 2.5 g, 42%, of the crude material was isolated after removal of the solvent.

13. O-(2,4-dinitrophenyl)hydroxylamine: 2.5 g of crude 14 were dissolved in 10 ml of trifluoroacetic acid and reacted for 30 min. at room temperature. The reaction mixture was placed in an ice water bath and an orange oil was noted to separate. After a few minutes of slow stirring the oil solidified. Efforts to recrystallize the product were unsuccessful. An IR spectrum of the material has, however, been obtained. See part II-B for the discussion of this spectrum.

C. Reactions of α-p-Dichlorotoluene and Hydroxylamine

Each of these reactions utilized α-p-dichlorotoluene, hydroxylamine, sodium methoxide and methanol solvent. The reactions were run for approximately 20 hours and worked-up as described. Product ratios were determined by comparing the areas under the methylene peaks for the various products. The key to the assignments can be found in the spectral discussion section, pages 47-51.

Hydroxylamine in methanol solution was prepared by reacting 0.575 equivalents of sodium methoxide with 0.50 equivalents of hydroxylamine hydrochloride in 500 ml of methanol.

Reaction 1: 3.2 g (0.02 mol) of α-p-dichlorotoluene were dissolved in 20 ml of methanol. To this solution were added 20 ml of 1M (0.02 mol) hydroxylamine with 0.0026 mol of excess sodium methoxide present. After reaction the solution was made basic via addition of 10% aqueous sodium hydroxide. A chloroform extraction of the basic solution was made and the extracts saved. Two 50 ml acid extractions of the chloroform layer were made with dilute hydrochloric acid. These extracts were neutralized and extracted twice with 50 ml of chloroform. The organic layer was dried over magnesium sulfate and the chloroform removed via evaporation at the rotavap. The product ratio was as follows:

N-(p-chlorobenzyl)hydroxylamine...77%

p-chlorobenzyl methyl ether.....23%

Little or no O-(p-chlorobenzyl)hydroxylamine was formed.

Reaction 2: 3.2 g (0.02 mol) of α-p-dichlorotoluene were dissolved in 20 ml of methanol to which were added 40 ml of 1 M (0.04 mol) hydroxylamine with 0.0052 mol of excess sodium methoxide present. The same workup as reaction 1 was employed and the ratio of products was as follows:

N-(p-chlorobenzyl)hydroxylamine...44%

O-(p-chlorobenzyl)hydroxylamine...56%

Reaction 3: The following methanol solution was prepared: 0.2M α-p-dichlorotoluene, 1.0 M hydroxylamine and 0.13 M sodium methoxide. The solution was worked up as usual and the following product ratio observed:

N-(p-chlorobenzyl)hydroxylamine...38%

O-(p-chlorobenzyl)hydroxylamine...41%

p-chlorobenzyl methyl ether.....21%

Reaction 4: The following reaction mixture was prepared: 0.5 M α-p-dichlorotoluene, 2.5 M hydroxylamine and 0.33 M sodium methoxide. The 2.5 M hydroxylamine solution was prepared by evaporating 60% of the solvent from the 1 M hydroxylamine solution at the rotavap. The product ratio was as follows:

O-(p-chlorobenzyl)hydroxylamine...94%

p-chlorobenzyl methyl ether..... 6%

p-Chlorobenzyl methyl ether: To 3.2 g (0.02 mol) of α-p-dichlorotoluene in methanol solution was added an excess of sodium methoxide. The product was acidified with hydro-

chloric acid and the sodium chloride filtered off. Methanol was removed at the rotavap. A water-chloroform separation of the product was made and the chloroform was dried over magnesium sulfate. Solvent was removed at the rotavap. Yield: 1.8 g, 58%.

p-Chlorobenzyl alcohol: To a 20 ml aqueous solution of 1.6 g (0.04 mol) of sodium hydroxide were added 3.2 g (0.02 mol) of α-p-dichlorotoluene. The mixture was stirred and refluxed for five hours and worked up by acidifying with hydrochloric acid and extracting with 50 ml of chloroform. The organic extract was dried over magnesium sulfate and the solvent removed at the rotavap. The product oil was returned to the flask, and placed in an aqueous solution containing excess hydroxide. A solid formed and was filtered to dryness. m.p. 60-65°C., ref.[30] 75°C.

p-Chlorobenzyl alcohol: A small, unweighed amount of O-(p-chlorobenzyl)hydroxylamine was placed in 10 ml of methanol. Approximately 0.1 g of palladium chloride was added to the solution and a hydrogen filled balloon was placed over the flask. The reaction was stirred for one hour and worked-up. The palladium was removed by suction filtration of the reaction mixture. The methanol was dried over magnesium sulfate and removed at the rotavap. The product structure was proved by comparing its NMR spectrum with that of p-chlorobenzyl alcohol prepared in an independent synthesis.

N-(p-Chlorobenzyl)hydroxylamine: In methanol solution were placed 1.4 g (0.02 mol) of hydroxylamine hydrochloride

and 5.06 ml of a 3.56 M (0.018 mol) sodium methoxide solution. To this 3.2 g (0.02 mol) of α-p-dichlorotoluene were added. The reaction occurred over a 20 hour period and the product was worked up in a manner similar to that described in reaction 1 of this section. Proof of structure was made by NMR analysis.

N-Mesitylenesulfonylhydroxylamine: In THF solution were placed 4.4 g (0.02 mol) of mesitylenesulfonylchloride, 6.9 g (0.10 mol) of hydroxylamine hydrochloride and 0.113 mol of sodium methoxide in methanol. Note that the hydroxylamine hydrochloride had been completely neutralized before it and the excess sodium methoxide were added to the THF solution. The mixture was stirred for a week at room temperature. All solvent was removed at the rotavap. Methanol (100 ml) was added to the product and filtered. Water was poured over the insoluble material in order to remove any water soluble materials left on the filter paper. The solution was at this point very cloudy, which indicated that an oil had formed. Four 50 ml ether extractions were made, combined, dried over magnesium sulfate and the solvent removed at the rotavap. The solid residue was dissolved in approximately 15 ml of ether and recrystallized with the addition of 70 ml of ether and recrystallized with the addition of 70 ml of petroleum ether. The flask was placed in the refrigerator for 48 hours. Yield: 0.2 g, 5%. m.p. 136-141°C. The m.p. of methyl-mesitylenesulfonate is 43.0-43.7°C.[31] and the m.p. of O-mesitylenesulfonylhydroxylamine is 80°C, decomposition.[18]

D. Kinetic Work

The first experiments conducted were attempts to repeat the work of Krueger et al.[13] with regard to the S_N2 reaction of $I^{\ominus}$ with hydroxylamine-O-sulfonate anion. Titrametric analysis of the $I_3^{\ominus}$ produced was chosen with $Na_2S_2O_3$ at the titrant.

$$2S_2O_3^{2-} + I_3^{\ominus} \rightarrow 3I^{\ominus} + S_4O_6^{2-}$$

Reaction 1: 1.6 g (10^{-2} mol) of KI and 7.55×10^{-4} mol of $HClO_4$ were dissolved in 100 ml of a 50% water-50% methanol (volume percent) solution. The reaction was begun with the addition of 8.53×10^{-2} g (7.55×10^{-4} mol) of NH_2OSO_3H. The results of the reaction indicated 1.13×10^{-2} mol $Na_2S_2O_3$/1g NH_2OSO_3H had been utilized.

Reaction 2: 8.0 g (5×10^{-2} mol) of KI and 8.33×10^{-4} mol of $HClO_4$ were dissolved in 100 ml of methanol-water solution. The reaction was begun with the addition of 9.40×10^{-2} g (8.32×10^{-4} mol) of NH_2OSO_3H. The results indicated 9.45×10^{-3} mol $Na_2S_2O_3$/1g NH_2OSO_3H were utilized.

Reaction 3: The same procedure was employed utilizing the following amounts of reagents: 8.0 g (5×10^{-2} mol) KI, 9.40×10^{-2} g (8.32×10^{-4} mol) NH_2OSO_3H, 8.33×10^{-4} mol HOAc, 25×10^{-4} mol NaOAc and 4.3×10^{-4} mol $HClO_4$. The results were 7.04×10^{-3} mol $Na_2S_2O_3$/1g NH_2OSO_3H.

It became apparent from these results that either the experimental technique was poor or the samples were obtained at various degrees of purity. It should be noted that in

none of these titrations and reactions had the effects of air oxidation of I^- to I_2 been considered, i.e. no blank was used.

Reaction 4: Attempts were made to dry the NH_2OSO_3H sample but these proved unsuccessful. The technique of Matsuguma et al.[32] was utilized in an effort to purge the system of O_2. The procedure involved adding 2 g (0.012 mol) KI, 0.5 g (0.006 mol) $NaHCO_3$, 10 ml H_2SO_4 and 0.1 to 0.2 g of NH_2OSO_3H to 150 ml of water. The reaction was timed and the results are shown in Table 2.

These results indicated (80.8 ± 1)% purity of the NH_2OSO_3H sample with the assumption that water was the impurity present. It was apparent that after 30 minutes the reaction had not gone to completion whereas after 90 minutes it had. It should also be noted that the O_2 was purged via the release of CO_2 from the reaction of H_2SO_4 and $NaHCO_3$.

$$H^{\oplus} + HCO_3^{\ominus} \longrightarrow H_2O + CO_2$$

Reaction 5: Due to these difficulties in obtaining dry samples of NH_2OSO_3H the work turned to kinetic studies of the reaction of $I^{\ominus}$ with O-mesitylenesulfonylhydroxylamine. The mechanism which was assumed by analogy to the work of Krueger et al.[13] was

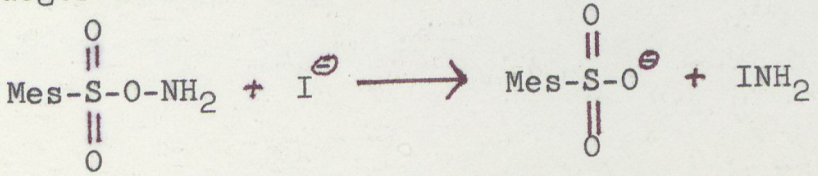
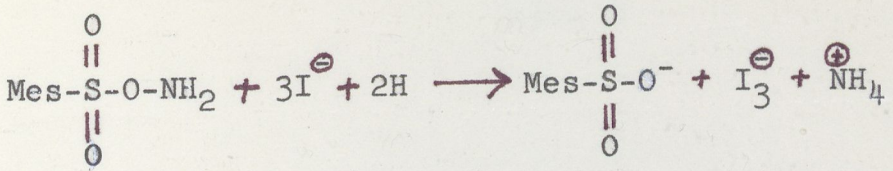


Table 2

Results of Reaction 4

t(min)	mol $Na_2S_2O_3$ x 10^2/g NH_2OSO_3H
30	1.10
90	1.26
1080	1.27

The balanced equation was as follows:



The work which was first performed was designed to determine the ratio of mols $S_2O_3^{2-}$ utilized/mol H consumed in the reaction. The reaction conditions were as follows: two, 100 ml methanol-water solutions with 0.0728 g (3.39×10^{-4} mol) and 0.0668 g (3.11×10^{-4} mol) of 4, 1.6 g (10^{-2} mol) KI, and 3.46×10^{-4} mol H_2SO_4 were prepared and placed in the flasks. After the reaction was permitted to preceed the ratio was calculated. The results are found in Table 3. The indicated balanced equation provides for a 1:1 ratio not the 2:1 ratio which the results of this experiment indicate.

Reaction 6: The work continued with 150 ml solutions of water-methanol and the reagents and times given in Table 4. Again the analytical method was titrametric with $S_2O_3^{2-}$ as the titrant. N_2 purging was employed to minimize air oxidation. These results can be given a pseudo-first order kinetics interpretation. Unfortunately they were not reproducible after repeated experimentation.

Reaction 7: The next technique which was employed was to run the experiments in 200 ml solutions and to withdraw and titrate 20 ml aliquots of the reaction mixture. The results from this portion of the work were erratic. The

Table 3

Calculated Ratio From Reaction 5

replicate	$Na_2S_2O_3$ mol/$H^{\oplus}$ mol
1	2.17 ± 20%
2	1.77 ± 15%

Table 4

Summary of Reaction 6

[4] x 10^3 M	[$H^{\oplus}$] M	[KI] x 10^2 M	t(min)	% reacted
3.10	0.00693	9.63	110	27.2
3.40	0.00693	9.63	110	27.0
1.46	2.4	6.4	100	64.
1.77	2.4	6.4	100	66.
1.94	0.24	0.64	90	60.5
4.18	2.4	32.0	90	99.
2.09	2.4	6.4	180	86.5

Table 5

Summary of Conditions for Reaction 7

$[I] \times 10^3$ M	$[H^{\oplus}]$ M	$[KI] \times 10^2$ M	t(min)	% reacted
1.46	2.4	6.4	30	60.8
1.58	2.4	6.4	30	60.2
1.46	2.4	6.4	60	60.5
1.58	2.4	6.4	60	60.2
1.46	2.4	6.4	120	64.5
1.58	2.4	6.4	120	69.1
1.46	2.4	6.4	180	64.2
1.58	2.4	6.4	180	67.6
1.46	2.4	6.4	240	76.8
1.58	2.4	6.4	240	76.0
1.46	2.4	6.4	1140	111.
1.58	2.4	6.4	1140	116.

Table 6

Summary of Conditions for Reaction 8

$[NH_2OH] \times 10^3$ M	$[H^{\oplus}]$ M	$[KI] \times 10^2$ M	t(min)	% reacted
2.17	2.4	6.4	30	0.
2.22	2.4	6.4	30	0.
2.17	2.4	6.4	60	0.9
2.22	2.4	6.4	60	1.0
2.17	2.4	6.4	120	3.6
2.22	2.4	6.4	120	0.0
2.17	2.4	6.4	180	0.
2.22	2.4	6.4	180	0.

Table 7

Summary of Results for Reaction 9

t(min)	absorbance	
	blank	experiment
2	0.057	0.172
4	0.068	0.178
6	0.075	0.186
8	0.078	0.191
10	0.088	0.195

problem here was essentially one of not being able to control the atmosphere within the reaction flask. Air oxidation of $I^{\ominus}$ to I_2 took place and it could not be corrected for with blank titrations. Table 5 provides conditions with appropriate corrections for the reaction just described.

Reaction 8: Following these poor results the reaction was changed and hydroxylamine (NH_2OH) in methanol-water was utilized instead of 4. A summary of the corrected data from these experiments is given in Table 6. It is noted that essentially no reaction occurred.

Reaction 9: Finally the reaction was changed back to nucleophilic substitution at nitrogen with $I^{\ominus}$ and 1 this time to be followed by spectrophotometric analysis of the $I_3^{\ominus}$ produced. The Beckman DU was utilized for these experiments and a wavelength of 400 nm was chosen. Once again problems were encountered. In this case the blank would at times increase in absorbance faster than the experimental solution. A sample of such data is given in Table 7.

II. SPECTRAL DATA AND INTERPRETATION

All IR spectra were run on the Perkin Elmer 237 Recording Infrared Spectrophotometer. NMR spectra were run on the Perkin Elmer R-24A High Resolution NMR Spectrometer.

A. O-Mesitylenesulfonylhydroxylamine

1. Mesitylenesulfonyl chloride: (spectrum 1) Table 8 clearly shows the O=S=O asymmetric and symmetric stretches

Table 8

Carbonyl and Sulfonyl Absorptions For

Compounds 1, 2 and 3

Compound	O=S=O asym. stretch exp. cm^{-1}	O=S=O asym. stretch ref. cm^{-1}	O=S=O sym. stretch exp. cm^{-1}	O=S=O sym. stretch ref. cm^{-1}	C=O exp. cm^{-1}	C=O ref. cm^{-1}
1	1375	~1380[33]	1175	~1170[33]		
2					1727	1725[18]
3	1370	1370[18]	1155	1155[18]	1735,1775	

to agree closely with values obtained from the literature. Peaks at 2950 cm^{-1} and 2990 cm^{-1} are noted and assigned to the sp^3 hybridized C-H stretch. The peak at 3040 cm^{-1} corresponds to the sp^2 hybridized C-H stretch.

2. t-Butyl N-hydroxycarbamate: (spectrum 2) The carbonyl stretching frequency indicated in Table 8 is noted to agree closely with the value cited from the literature. In addition N-H and O-H stretches are assigned to 3275 cm^{-1} and 3400 cm^{-1} respectively. The C-H stretch is noted at 2940 cm^{-1} and 2980 cm^{-1}. The bands at 1370 cm^{-1} and 1395 cm^{-1} are assigned to the t-butyl C-H bending vibrations[34].

3. t-Butyl N-mesitylenesulfonyloxycarbamate: (spectrum 3) Table 8 shows that the sulfonyl symmetric and asymmetric stretches agree closely with the reference values. The peaks at 1735 cm^{-1} and 1775 cm^{-1} are thought to be coupled carbonyl-sulfonyl stretches. No literature information is available to confirm of deny this speculation. Other peaks of interest are the 3365 cm^{-1} N-H stretch and the 1375 cm^{-1} C-H bend from the t-butyl group.

4. O-Mesitylenesulfonylhydroxylamine: (spectrum 4) The infrared spectrum of this compound was obtained in methylene chloride solvent. A spectrum of the solvent (5) is provided so the reader can take cognizance of the solvent absorptions. The peaks at 3260 cm^{-1} and 3350 cm^{-1} are assigned to the primary amine N-H stretch. The sulfonyl asymmetric and symmetric stretches are assigned to 1360 cm^{-1}

and 1160 cm^{-1} respectively.

7a. and 7b: (spectra 6 and 7) The infrared spectrum of this mixture of compounds is quite complex indeed. It should be noted that the solvent chosen was methylene chloride which clearly introduced its own absorptions to the spectrum. The peaks at 3530 cm^{-1} and 3360 cm^{-1} correspond to the O-H and N-H stretches respectively. The peak at 3040 cm^{-1} is due to phenyl C-H stretching while that centered at 1770 cm^{-1} corresponds to the carbonyl stretch. The NMR spectrum can be rationalized as follows: (all positions are corrected) The peak at 2.1 ppm corresponds to acetone impurity. The multiple peaks centered at 5.1 ppm and integrating for 2 protons is assigned to the methylene peaks for the two possible products. The broad peak centered at 7.3 ppm and integrating for 8 protons (a 7 proton integration would have been an exact correspondence) is assigned to the phenyl and all exchangeable, N-H and O-H, protons.

8a. and 8b: (spectra 8 and 9) The NMR spectrum at first appears to be difficult to interpret. However, after study some sense can be made of it. In addition to the two indicated products, 8a and 8b, it is apparent that triethylamine hydrochloride is present. The triplet at 1.35 ppm integrating for 9 protons is assigned to the methyl protons of triethylamine hydrochloride while the multiplet centered at 3.1 ppm and integrating for 6 protons is assigned to the methylene protons of triethylamine hydrochloride. The nitrogen proton is assigned to the singlet at 4.98 ppm. The peak at 2.3 ppm

integrating for approximately 3 protons is assigned to the para methyl group of the mesitylenesulfonyl ring while the peaks at 2.6 ppm and 2.7 ppm and integrating for a total of approximately six protons are assigned to the ortho methyl groups on each of the respective molecules. The peaks at 5.1 ppm and 5.2 ppm which integrate for a total of 2 protons are assigned to the methylene protons. The methylene peak for 8a is assigned to 5.1 ppm while 8b is assigned to 5.2 ppm. The N-H and phenyl protons are assigned to the peaks which appear at 6.9 ppm and 7.4 ppm even though the integration does not correspond exactly to this assignment. The IR spectrum clearly demonstrates N-H stretching at 3400 cm^{-1} and carbonyl absorptions at 1760 cm^{-1} (8a) and 1810 cm^{-1} (8b).

9a. and 9b: (spectrum 10) The infrared spectrum of the hydrogenation products clearly demonstrates the presence of an O-H stretch (9a) at 3525 cm^{-1} and possibly the broad peak at 3400 cm^{-1} and primary N-H stretches (9b) at 3340 cm^{-1} and 3430 cm^{-1}. Sulfonyl symmetric and asymmetric stretches are noted at 1160 cm^{-1} and 1350 cm^{-1} respectively.

9b. Mesitylenesulfonamide: (spectrum 11) The IR spectrum of mesitylenesulfonamide clearly demonstrates the primary N-H stretches at 3340 cm^{-1} and 3440 cm^{-1} as well as the sulfonyl stretches at 1160 cm^{-1} and 1340 cm^{-1}. With this spectral evidence the proof of structure 9b from the hydrogenation is completed. Structures 8b and 7b are proved by inference.

B. O-(2,4-Dinitrophenyl)hydroxylamine

11. Ethyl acetohydroxamate: (spectrum 12) The neat infrared spectrum clearly demonstrates a broad, strong O-H stretch at 3375 cm^{-1} as well as C-H stretches at 2940 cm^{-1} and 2980 cm^{-1}. The C=N stretch assigned to the 1665 cm^{-1} frequency agrees with the literature value for primary imines[33].

12. Ethyl O-(2,4-dinitrophenyl)acetohydroxamate: (spectra 13 and 14) A slightly wet infrared spectrum which was run utilizing nujol solvent (see spectrum 15 for nujol peaks) clearly demonstrates the phenyl C-H stretching vibration at 3120 cm^{-1}. The peak at 1632 cm^{-1} is assigned to the C=N stretch while the peaks at 1605 cm^{-1}, 1530 cm^{-1}, 1520 cm^{-1} and 1500 cm^{-1} are assigned to the C=C stretches for the phenyl ring. The NMR spectrum clearly demonstrates the presence of this compound. The singlet at 2.2 ppm integrating for 3 protons is the methyl group. The triplet at 1.4 ppm (3H) and the quartet at 4.24 ppm (2H) clearly represent the methyl and methylene protons of the ethyl group. The doublet at 7.85 ppm represents the phenyl proton ortho to the acetohydroxamate position. The doublet of doublets at 8.4 ppm represents the proton meta to the acetohydroxamate and ortho to one of the nitro groups. The doublet at 8.85 ppm is due to the proton ortho to both of the nitro groups.

13. O-(2,4-Dinitrophenyl)hydroxylamine (from 12): (spectrum 16) The presence of a broad peak at 3520 cm^{-1} (an O-H stretch) indicates the use of a wet sample, the presence of 2,4-dinitrophenol or both. The N-H stretching frequencies

have been assigned to 3090 cm^{-1} and 3120 cm^{-1} [19]. The aromatic C-H stretch is found at 3040 cm^{-1}. The C-C aromatic stretching frequencies have been assigned to 1602 cm^{-1}, 1580 cm^{-1}, 1548 cm^{-1} and 1535 cm^{-1}.

14. t-Butyl N-(2,4-dinitrophenoxy)carbamate: (spectrum 17) The spectrum peaks were assigned as follows: The singlet at 1.5 ppm and integrating for 9 protons was assigned to the t-butyl protons. The doublet at 7.75 ppm, the doublet of doublets at 8.45 ppm and the doublet at 8.85 ppm each integrate for 1 proton and are assigned to the same phenyl positions as the corresponding peaks of compound 12. The singlet at 8.07 ppm integrating for 1 proton is assigned to the N-H proton. The peak at 1.27 ppm is considered an impurity which is probably due to one or more of the recrystallization solvents.

13. O-(2,4-Dinitrophenyl)hydroxylamine (from 14): (spectrum 18) The infrared spectrum of the material synthesized from the acid catalyzed cleavage of 14 is presented. The double peak at 3510 cm^{-1} and 3570 cm^{-1} is thought to be at too high a frequency to be due to primary amine N-H stretching. This spectrum is by no means considered a proof of the structure.

C. Reactions of α-p-Dichlorotoluene With Hydroxylamine

α-p-Dichlorotoluene: (spectrum 19) The singlet at 4.45 ppm (2H) is assigned to the methylene protons while that at 7.22 ppm (4H) is assigned to the phenyl protons.

p-Chlorobenzyl methyl ether: (spectrum 20) Each singlet peak found in the spectrum is assigned as follows: The peak at 3.30 ppm (3H) is due to the methyl protons. The peak at 4.35 ppm (2H) is assigned to the methylene protons. Finally, the peak at 7.22 ppm (4H) is due to the phenyl protons.

Reaction 1: (spectrum 21) Not all of the peaks could be properly assigned due to sample impurities. However, those which could be assigned are given here. The singlet at 2.1 ppm is due to acetone. The singlet at 3.15 ppm is assigned to the methyl group of the methyl ether product. The singlet at 3.78 ppm is assigned to the methylene group of N-(chlorobenzyl)hydroxylamine. The singlet at 4.39 ppm is due to methylene protons of the methyl ether while that at 4.49 ppm is due to the methylene protons of the starting material. The O-(p-chlorobenzyl)hydroxylamine methylene protons are to be found at 4.58 ppm. All rapidly exchanging protons (N-H and O-H) are found under the broad peak at 5.65 ppm. All phenyl protons are assigned to the peak at 7.26 ppm.

Reaction 2: (spectrum 22) The peak assignments are as follows: The methylene protons for the N- and O-(p-chlorobenzyl)hydroxylamine are found at 3.88 ppm and 4.59 ppm respectively. Exchanging N-H and O-H protons are found under the broad peak at 6.0 ppm. The phenyl protons are assigned to the peak at 7.26 ppm.

Reaction 3: (spectrum 23) The following assignments are made: The methyl and methylene protons of the methyl ether are found at 3.3 ppm and 4.35 ppm respectively. The methylene peaks for the starting material, N-(p-chlorobenzyl)hydroxylamine, and O-(p-chlorobenzyl)hydroxylamine are found at 4.45 ppm, 3.82 ppm and 4.54 ppm. respectively. Exchanging protons are found at 5.9 ppm. The phenyl protons are assigned to the peak at 7.24 ppm.

Reaction 4: (spectra 24 and 25) The methyl and methylene peaks due to the methyl ether are found at 3.30 ppm and 4.32 ppm respectively. The methylene peak for the O-(p-chlorobenzyl)hydroxylamine is found at 4.55 ppm. Exchanging protons are observed at 5.3 ppm while all phenyl protons appear at 7.2 ppm. D_2O exchange of the products yielded the same spectrum less the peak at 5.3 ppm (spectrum 25).

p-Chlorobenzyl alcohol (from hydroxide reaction): (spectrum 26) The singlet at 2.35 ppm (1H) is assigned to the O-H proton. The methylene protons for starting material and product are found at 4.50 ppm and 4.56 ppm respectively. All phenyl protons are found at 7.24 ppm.

p-Chlorobenzyl alcohol (from hydrogenation): (spectra 27, 28, and 29) In spectrum 27 the peak at 2.14 ppm is attributed to acetone impurity. The broad peak from 2.3 ppm to 3.3 ppm is attributed to the O-H proton. The peaks at 4.59 ppm and 7.25 ppm are assigned to the methylene and phenyl protons respectively. After D_2O exchange (spectrum 28) the elimination of the broad peak from 2.3 ppm to 3.3 ppm is

observed. A drop of trifluoroacetic acid is added to a sample (spectrum 29) of the product and an exchanging hydrogen is noted at 5.2 ppm.

N-Mesitylenesulfonylhydroxylamine: (spectra 30, 31, 32 and 33) Spectrum 30 is a spectrum of the neat DMSO d_6 solvent. Protonated DMSO is noted at 2.45 ppm, water at 3.22 ppm and chloroform at 8.20 ppm. The chloroform peak was confirmed by spectrum 31 where a drop was added to the tube. The increased peak height at 8.20 ppm is noted. Spectrum 32 demonstrates the product with the peak assignments made as follows: The peak at 2.25 ppm (3H) is assigned to the ortho methyl protons. Note that under the 2.57 ppm peak is protonated DMSO, Water is noted at 3.30 ppm. The phenyl protons are assigned to the 7.05 ppm singlet. The N-H and O-H protons are assigned to the two doublets (AB splitting pattern) at 9.35 ppm and 9.2 ppm respectively. The N-H proton is thought to be more deshielded because it is between two electron withdrawing groups while the O-H proton is only adjacent to one electron withdrawing group. After D_2O exchange (spectrum 33) we note a strong HOD peak at 3.87 ppm and elimination of the peaks at 9.35 ppm and 9.2 ppm indicating those were exchangeable protons. The spectrum has been shifted 0.50 ppm up-field.

N-(p-Chlorobenzyl)hydroxylamine: (spectra 34, 35 and 36) Spectrum 34 is presented here in an attempt to prove the structure of N-(p-chlorobenzyl)hydroxylamine. It is noted

that the evidence is not totally consistent, but a flawed interpretation is presented. The doublet centered at 3.82 ppm and integrating for approximately 2 protons is assigned to the methylene group and is thought to be split by the N-H proton. The singlet at 5.96 ppm and integrating for 1.35 protons is thought to be due to N-H and O-H protons which are not in rapid exchange. Why the N-H proton is not split by the methylene protons cannot be explained. The phenyl protons are assigned to the singlet at 7.32 ppm and it is noted that this peak integrated for 4.46 protons. If a drop of trifluoroacetic acid is added (spectrum 35) to the tube we note the peak at 5.96 ppm is shifted downfield to 9.18 ppm. It is also noted that the doublet at 3.82 ppm has begun to collapse into a singlet. If more trifluoroacetic acid is added (spectrum 36) we note a triplet centered at 4.28 ppm has formed with peaks of equal height and with J values of approximately 3 Hz. It is thought the methylene protons have been split by the nitrogen adjacent to them. A reference to ^{14}N splitting has been found which is consistent with the splitting constant[35]. The author realizes this interpretation is flawed but has included it as a partial proof of structure.

CONCLUSION

That the synthesis of O-(2,4-dinitrophenyl)hydroxylamine was difficult was not surprising. Carpino[22], reported O-mesitylenesulfonylhydroxylamine to be unstable if left at room temperature for an extended length of time. In addition O-p-toluenesulfonylhydroxylamine burst into flames whenever he attempted to isolate it. Illvespää[26] reported that attempts to synthesize O-(2,4-dinitrophenyl)hydroxylamine from ethyl O-(2,4-dinitrophenyl)acetohydroxamate always ended with the 2,4-dinitrophenol. The trend appears to be the better the electron withdrawing substituents the more unstable the molecule. Nevertheless, Tamura et al.[19] and Sheradsky[26] have reported the successful synthesis of this compound and have apparently been able to obtain spectral and physical data for it.

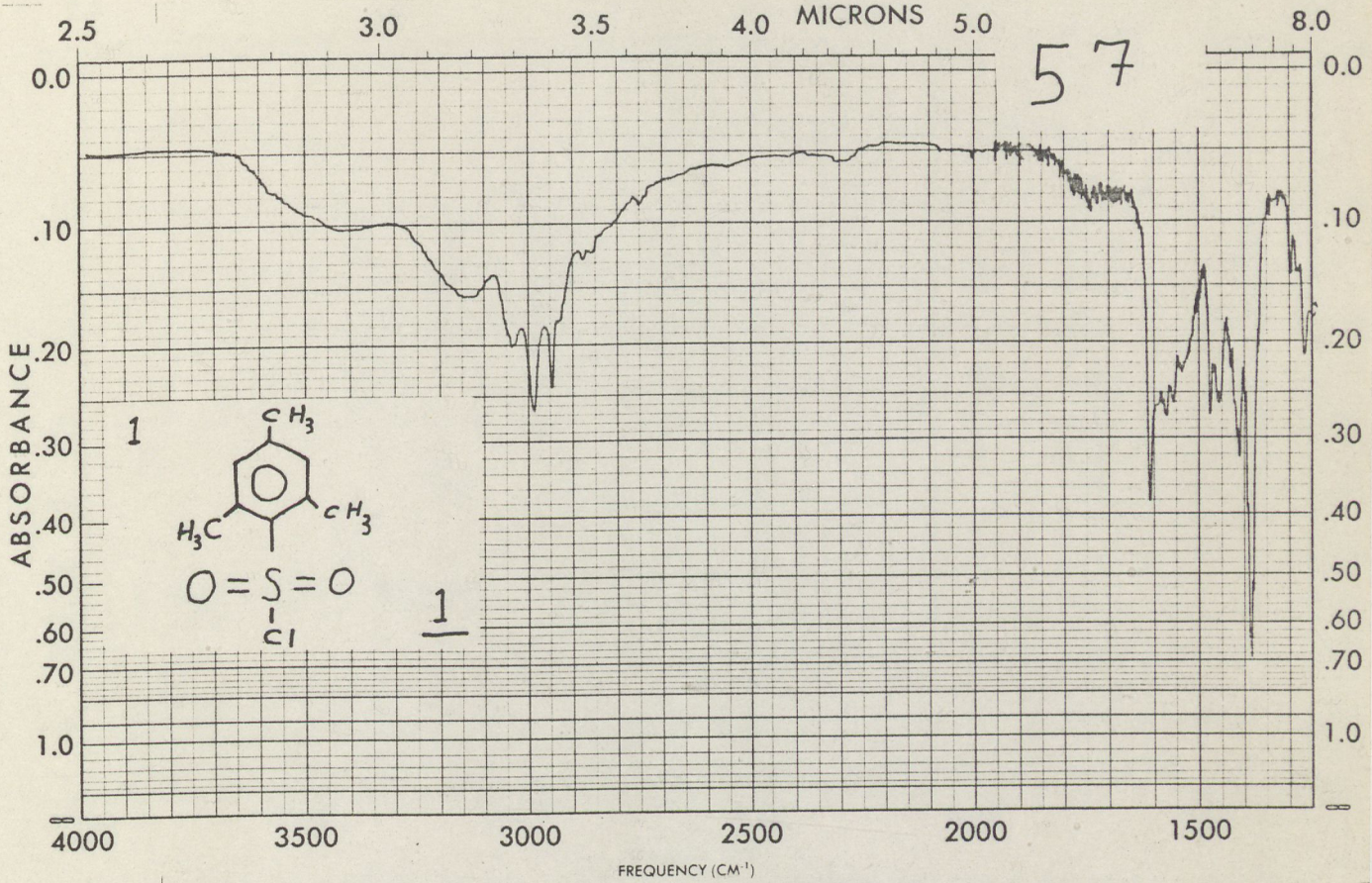
It is likely that an O-mononitrophenylhydroxylamine will be more stable under conditions chosen for its synthesis. Since the model studies of S_N2 reactions of hydroxylamine with α-p-dichlorotoluene were successful in producing exclusively O-substituted hydroxylamine it is thought the conditions of reaction 4 (Table1) can be employed in a reaction of 2-nitro-1-chlorobenzene or 4-nitro-1-chlorobenzene with hydroxylamine. It is thought that the O-substituted hydroxylamine product will be yielded via an S_NAr mechanism.

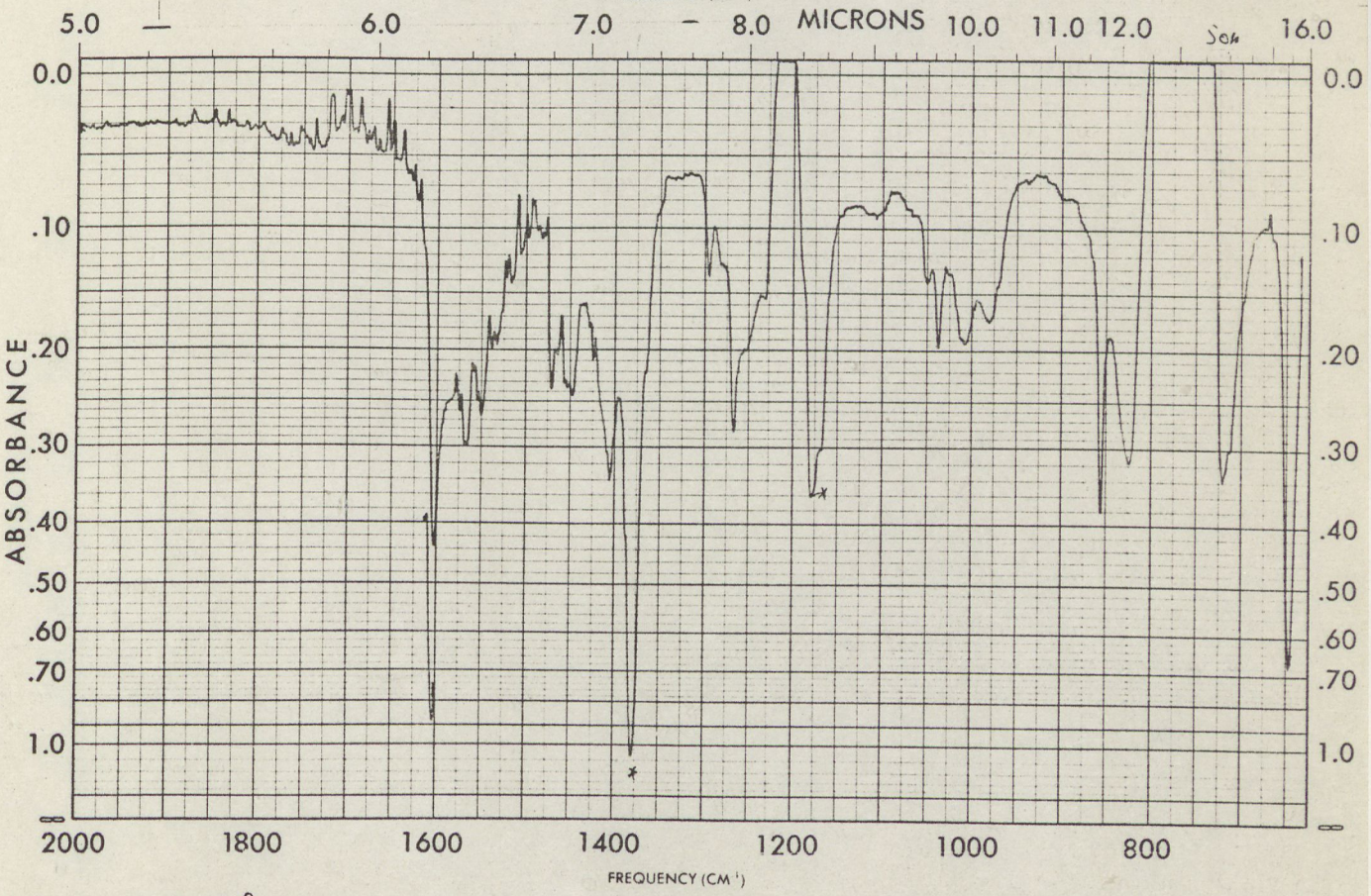
Once the O-(nitrophenyl)hydroxylamine is synthesized its UV-visible spectrum and the spectrum of the nitrophenolate anion can be obtained in a solvent suitable for running the substitution reactions. The substitution reactions can then

be run with a variety of nucleophiles and the kinetics followed by spectrophotometric methods.

APPENDIX

Each spectrum presented contains more than one number. The number in the upper right corner is the page number. The underlined numbers next to the structural drawings refer to structure numbers which appear throughout the text. The number which is not underlined and is next to the structural drawing is the spectrum number.





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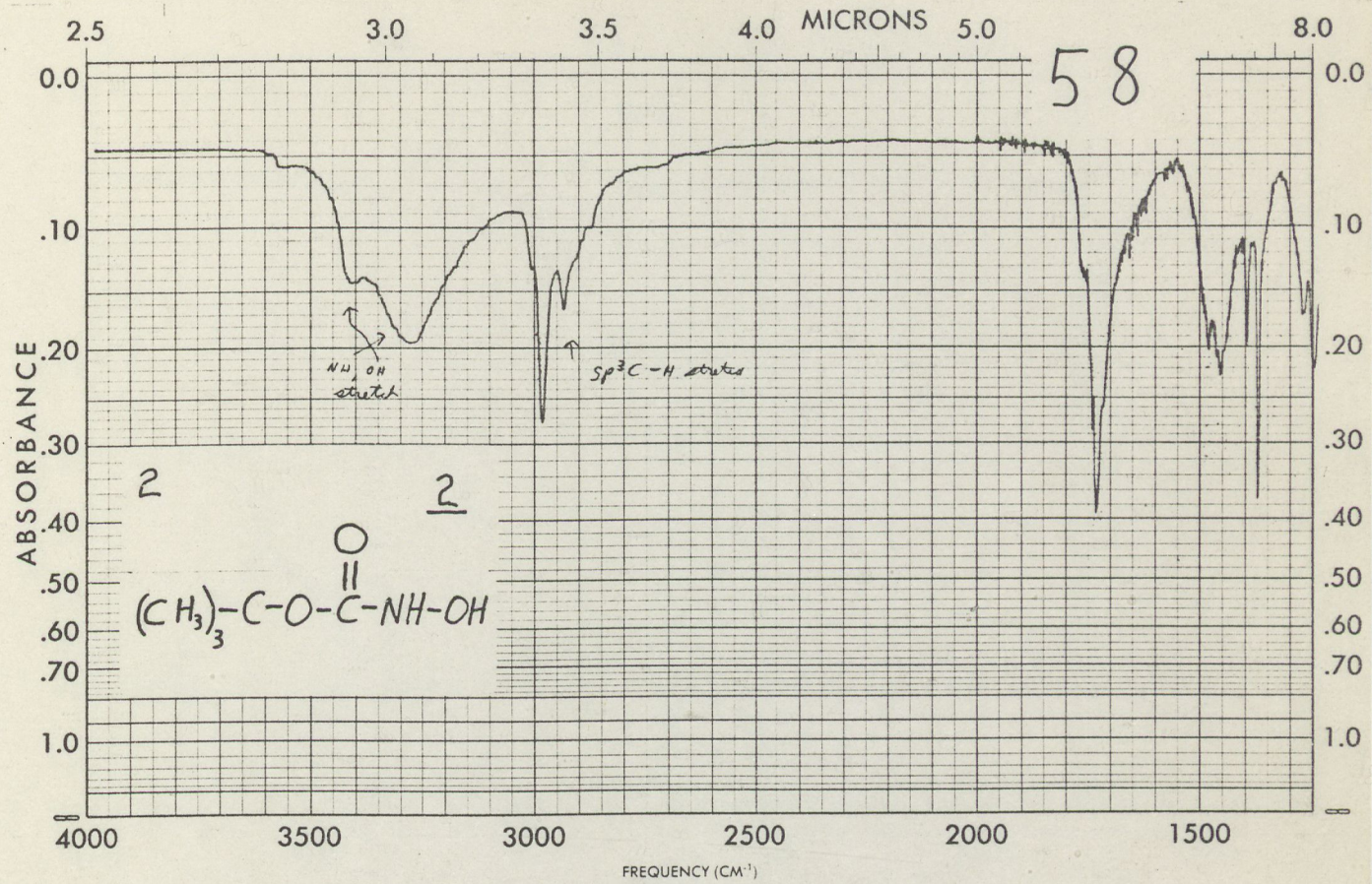

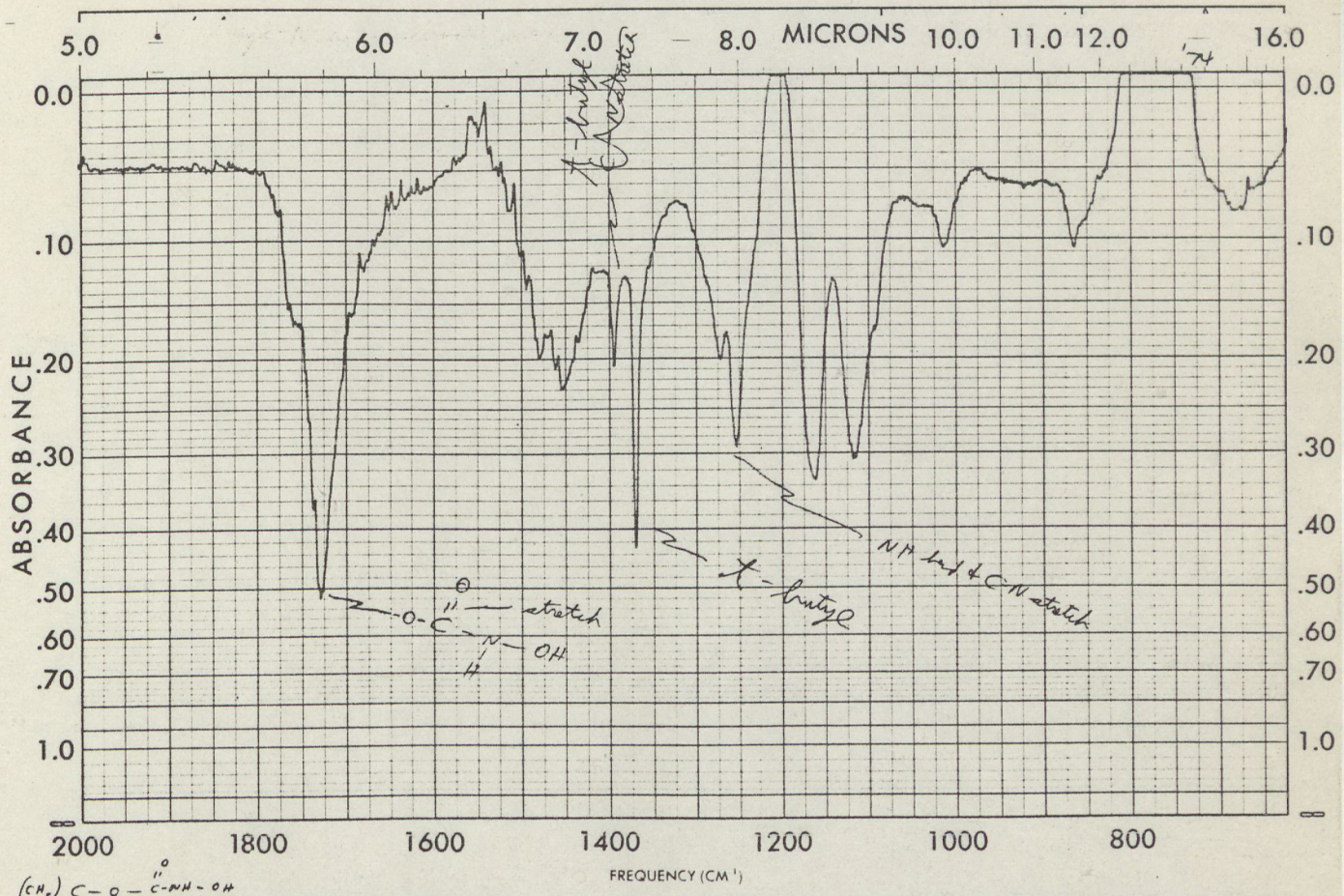

$(CH_3)_3C-O-\overset{O}{\overset{\|}{C}}-NH-OH$

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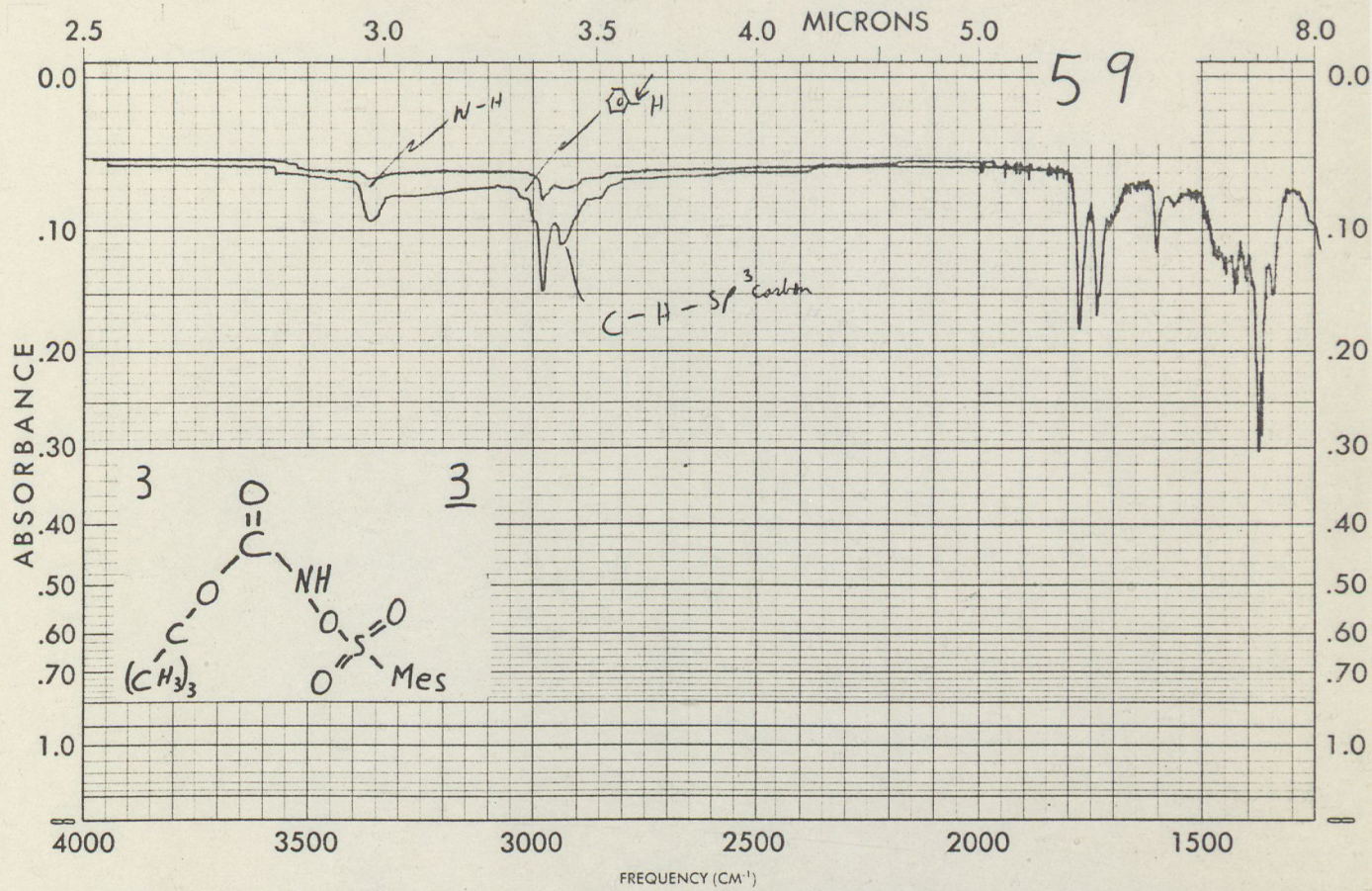
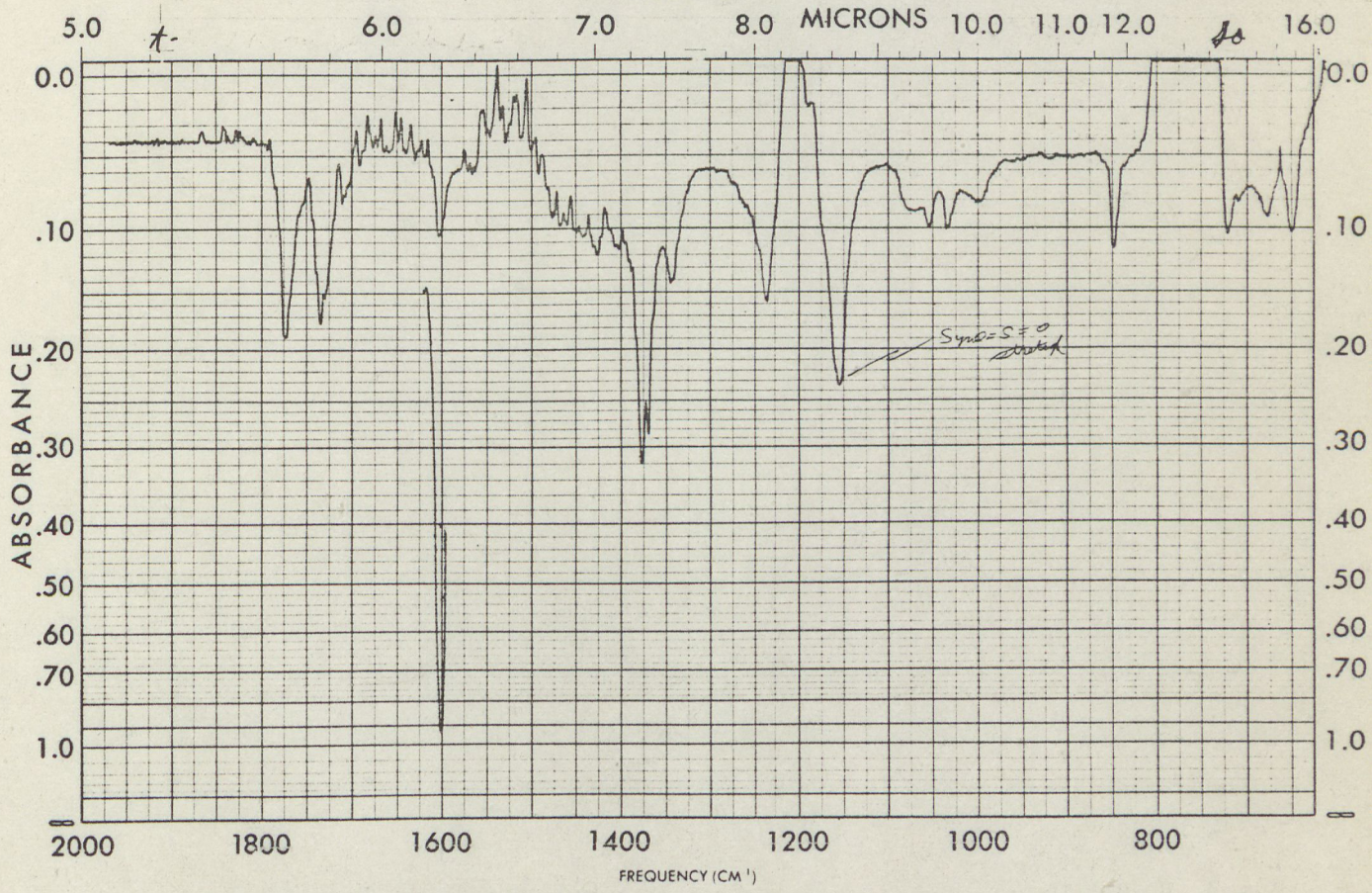
	REFERENCE CCl_4		





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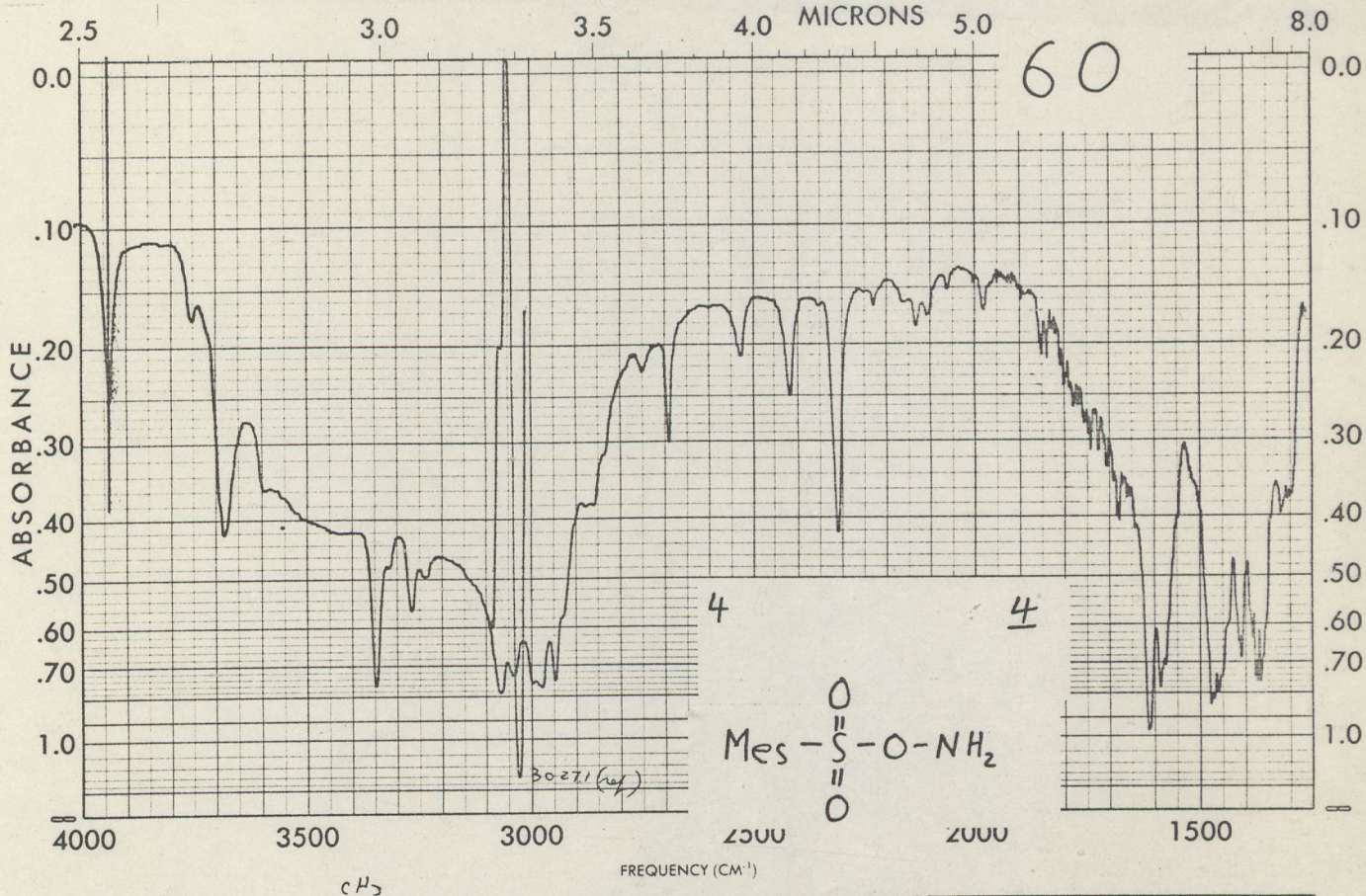
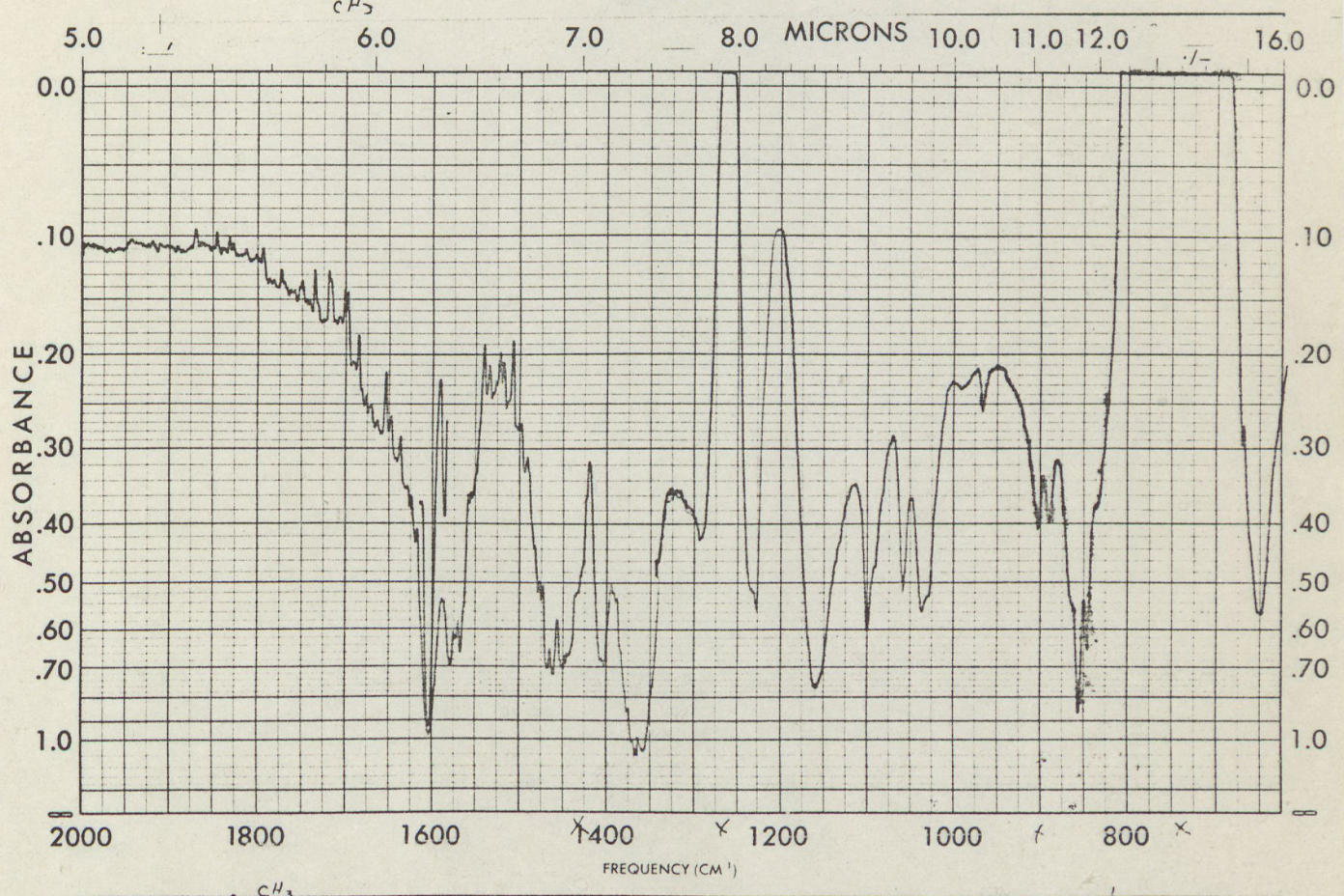
	REFERENCE CCl4		

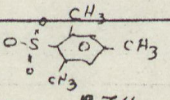
60

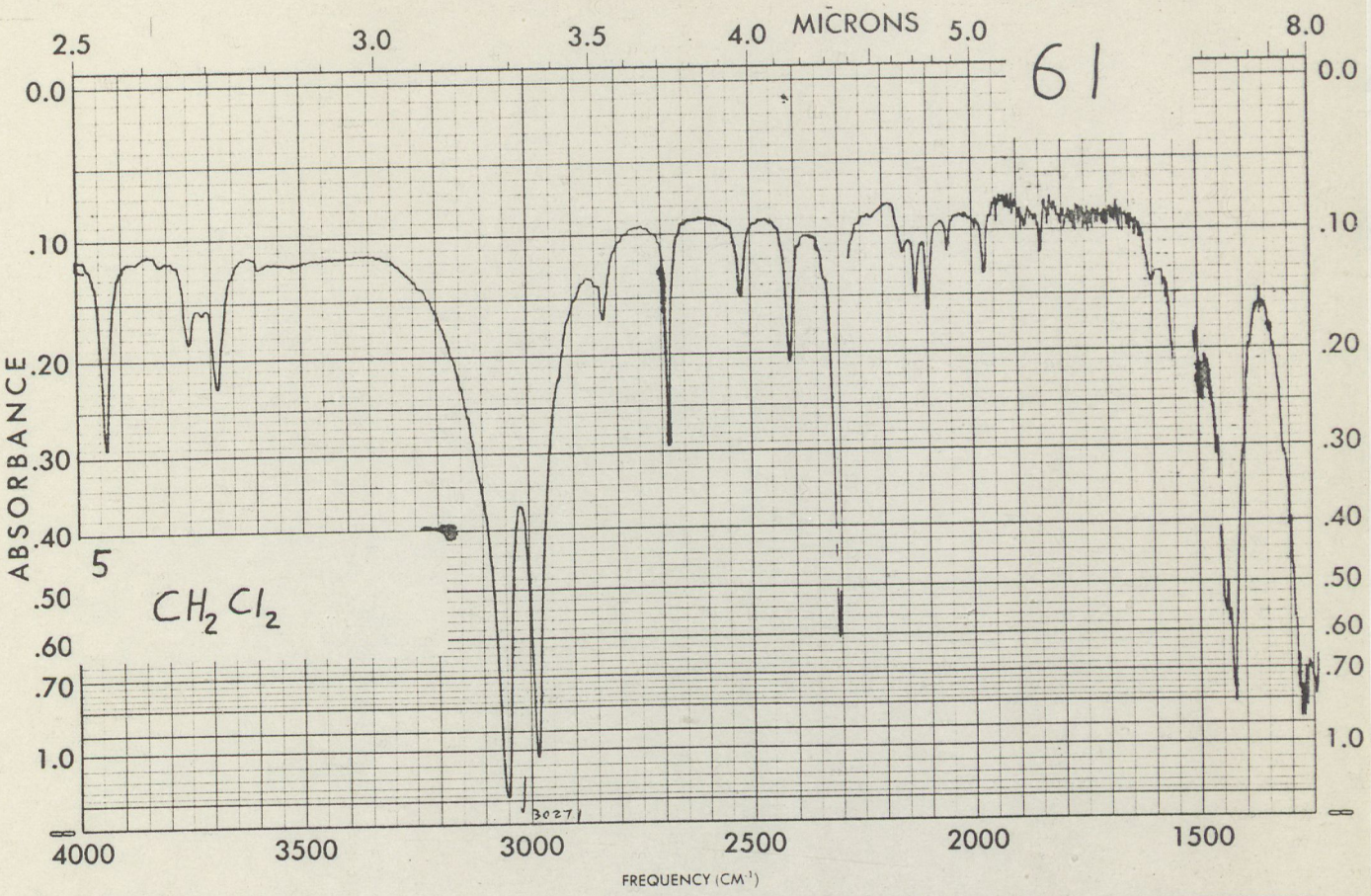


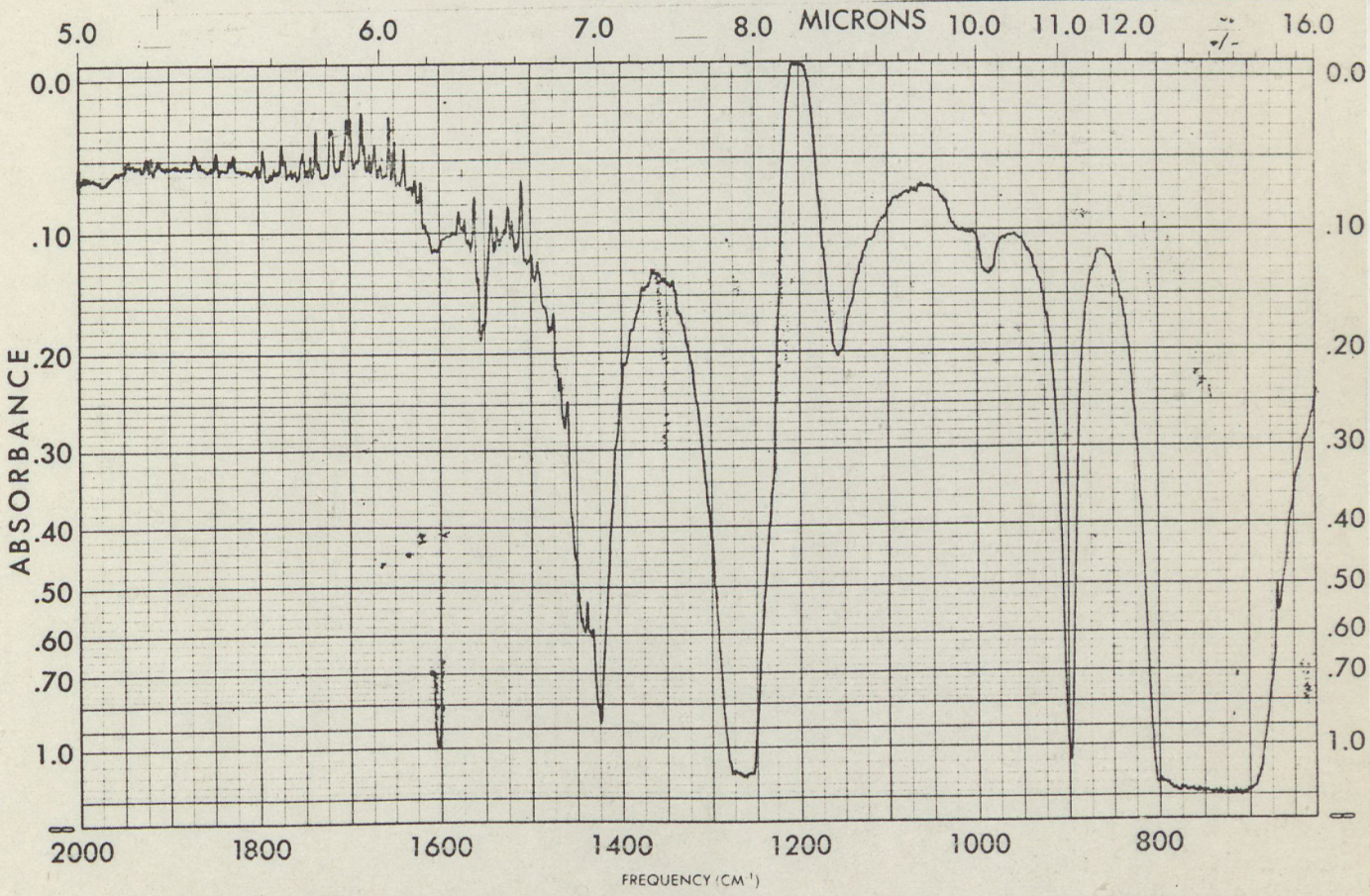
4 4

$Mes-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-O-NH_2$



SAMPLE 	CURVE NO.	SCAN SPEED FAST	OPERATOR Sommer
ORIGIN Spring, 1974	CONC. neat.	SLIT 30	DATE 7/17/74
SOLVENT CH_2Cl_2	CELL PATH 0.1mm	REMARKS 1600, 1580, 1460, 1402, 1370, 1100, 1060, 1035	
	REFERENCE CH_2Cl_2		





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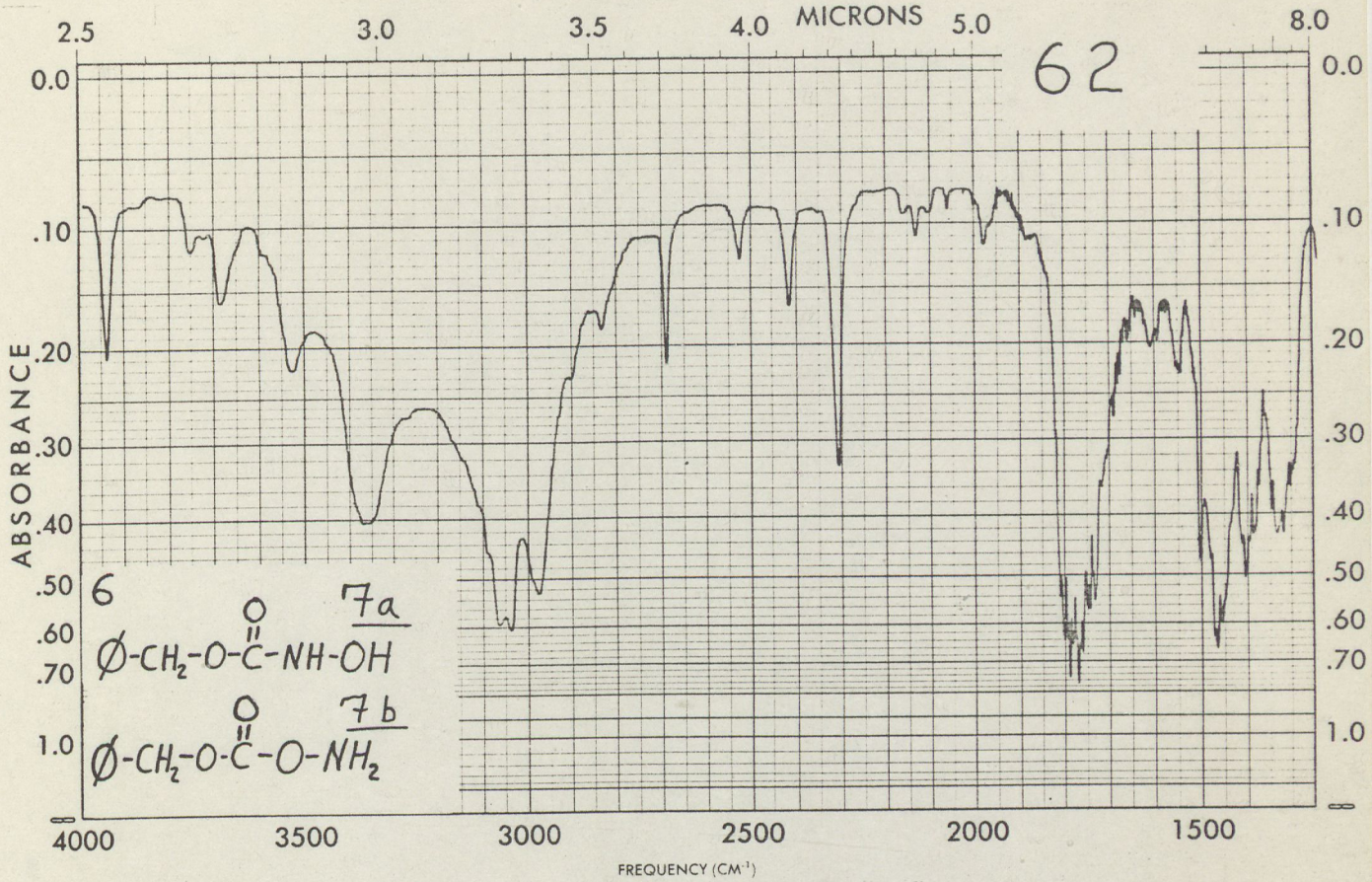
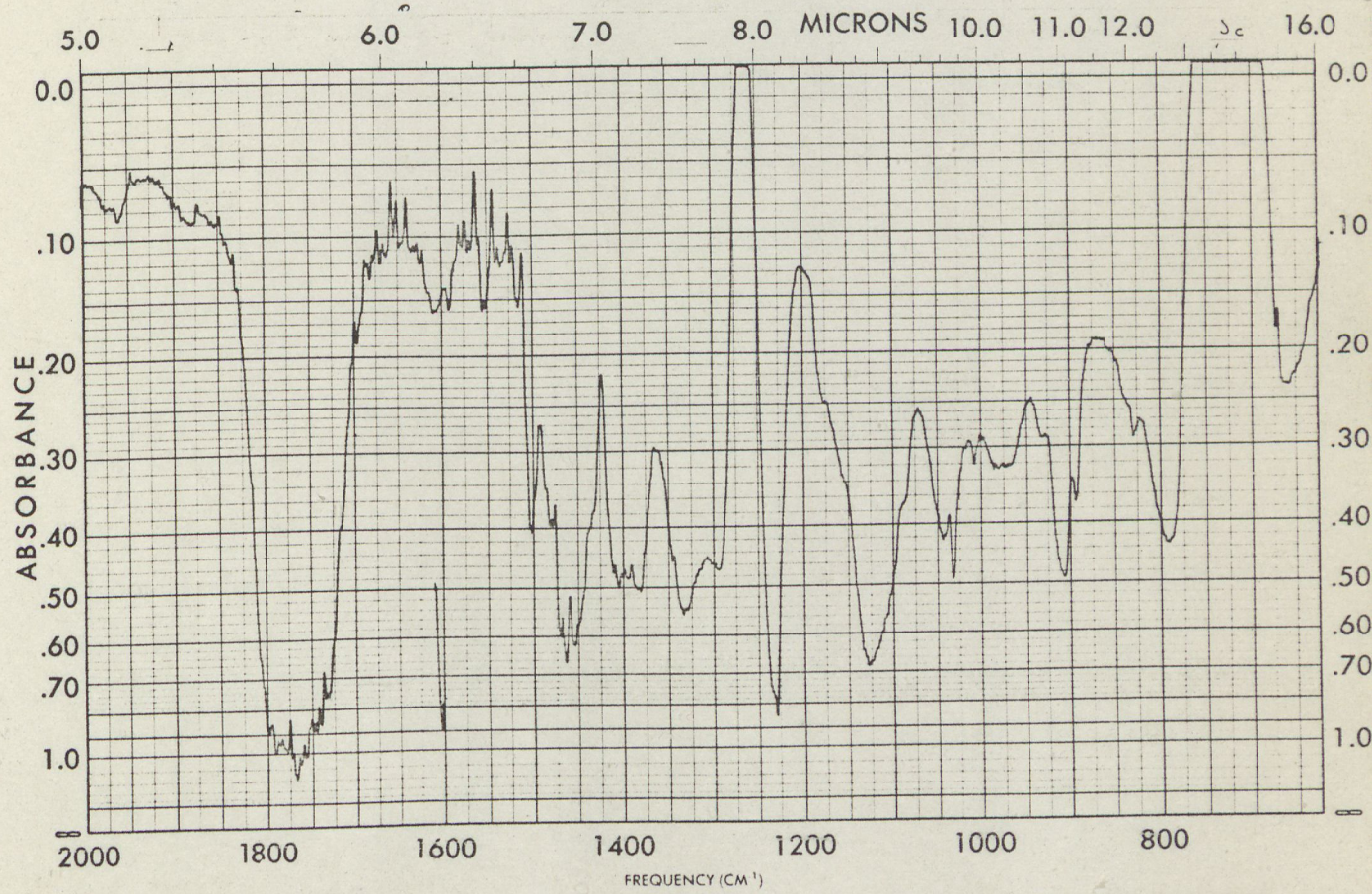
SOLVENT ~~CH~~ none	REFERENCE air		





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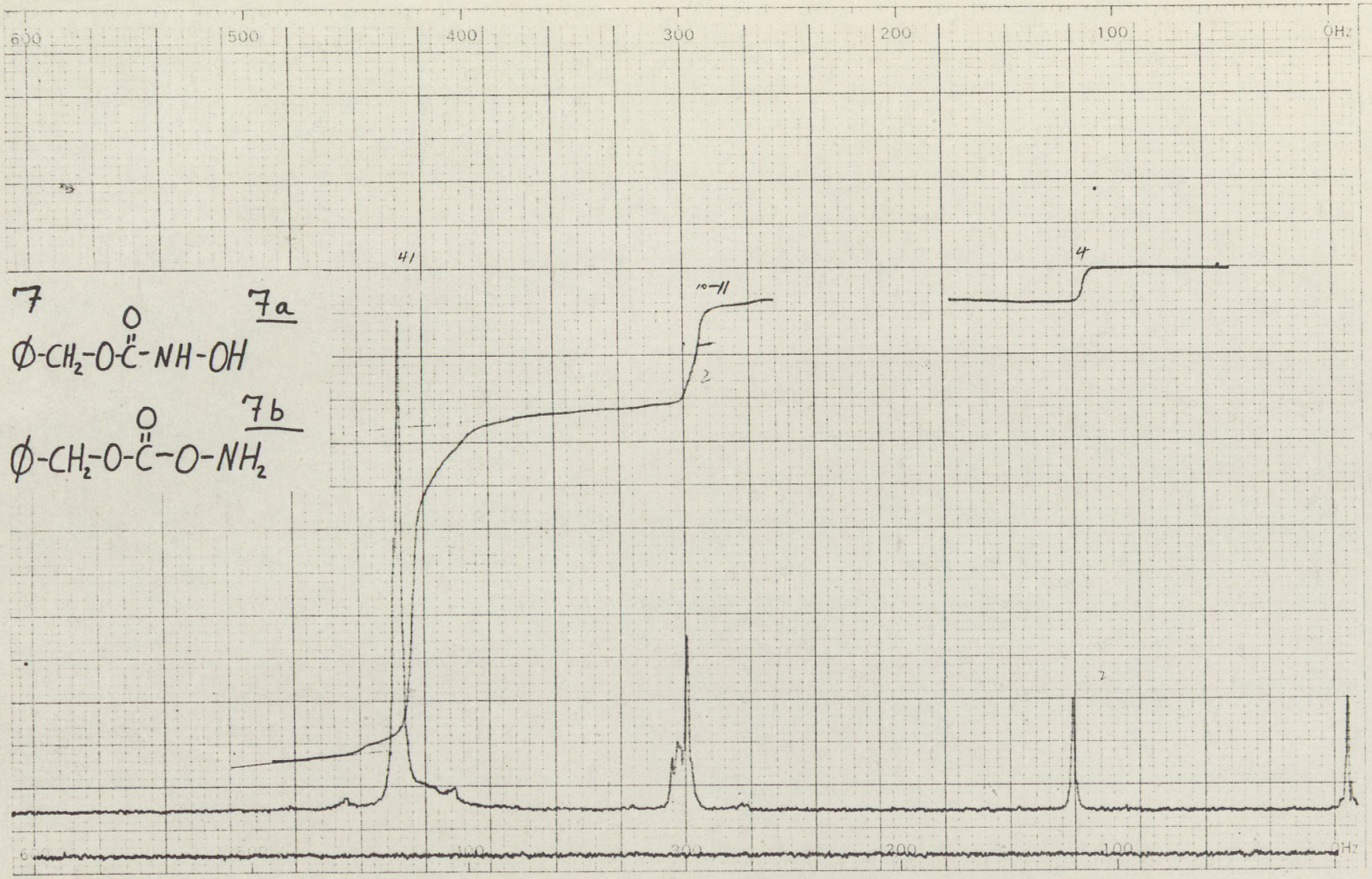
SOLVENT CH2Cl2	REFERENCE CH2Cl2		

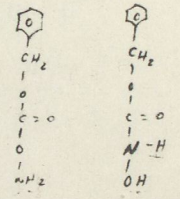


7 $\phi\text{-}CH_2\text{-}O\text{-}\overset{O}{\overset{\|}{C}}\text{-}NH\text{-}OH$ **7a**

$\phi\text{-}CH_2\text{-}O\text{-}\overset{O}{\overset{\|}{C}}\text{-}O\text{-}NH_2$ **7b**

^1H SPECTRUM NO. : 6

SAMPLE :



REFERENCE : TMS
SOLVENT : $CDCl_3$
CONC : ~10%

AMPLITUDE :
SPECTRUM : 9
INTEGRAL : 9

H_1 LEVEL : ✓

H_2 LEVEL :

GAIN : ✓

SWEEP WIDTH :
NOR ✓ SCALE EXP

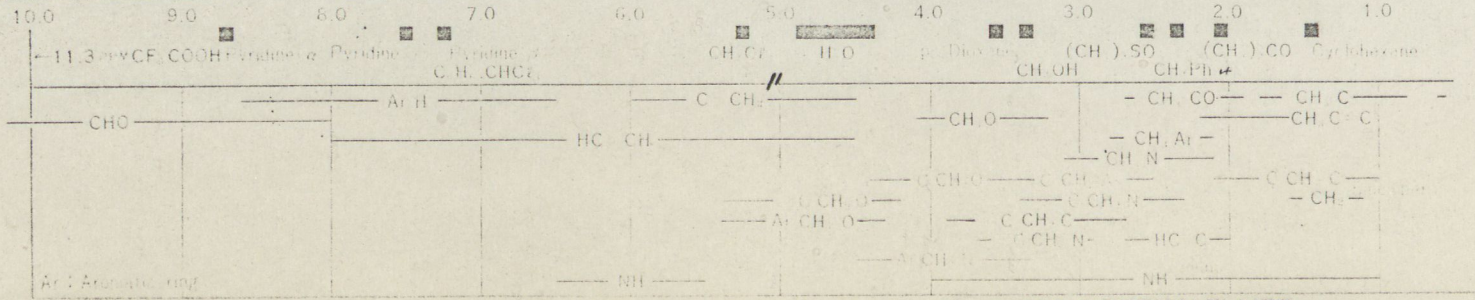
SHIFT : 0

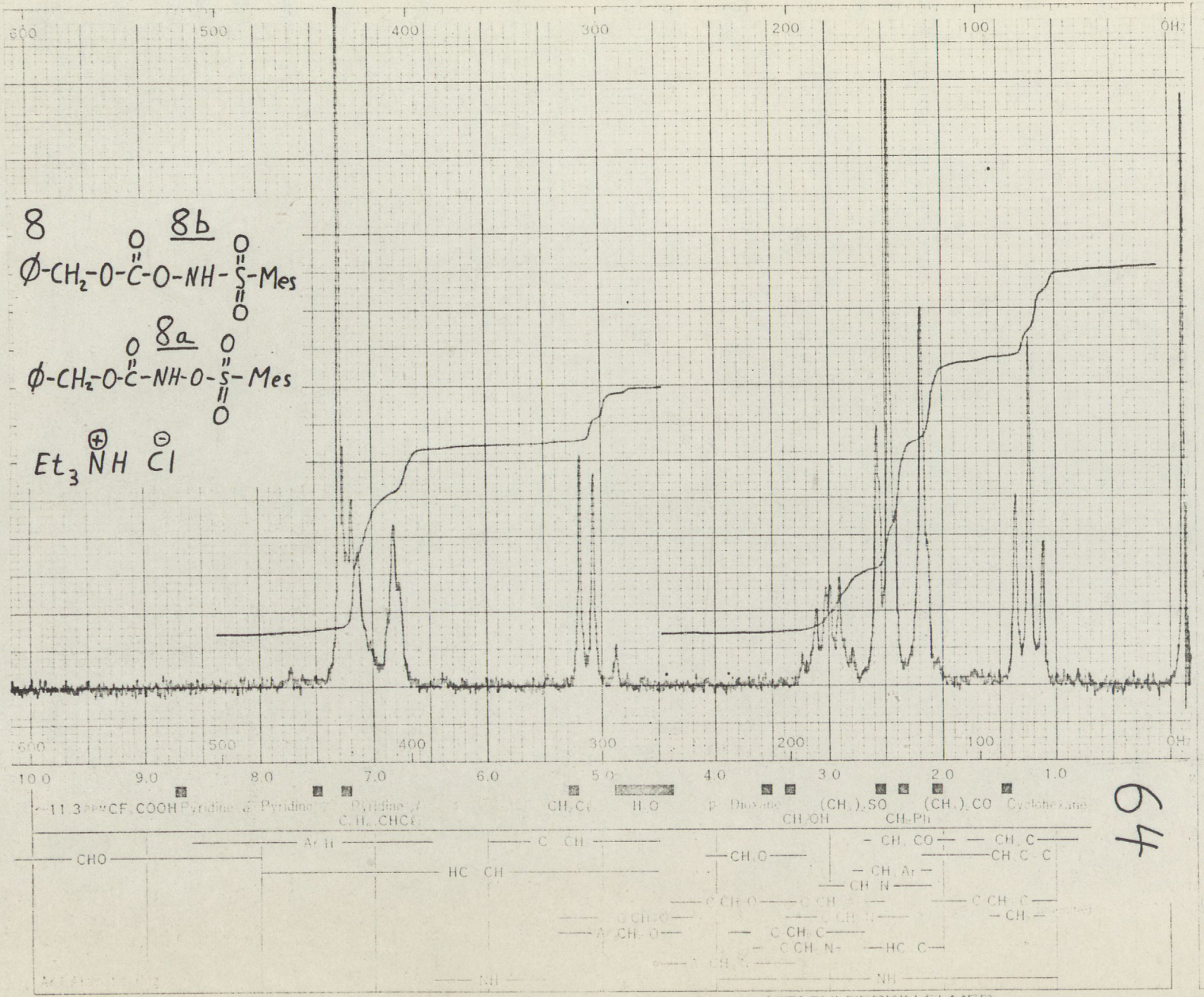
SWEEP TIME :
✓ 300 150SEC ☐ SEC

DATE : 11/1/74

OPERATOR : R. Sommer

REMARKS :
Lower spec
10–20 ppm
AMP = 10.
Peak at 2 ppm = acetone





^{1}H SPECTRUM NO. : 5

SAMPLE :

$(Et)_3\overset{\oplus}{N}-H\ \overset{\ominus}{Cl}$

Ø-CH2-O-C(=O)-N(H)-O-S(=O)2-Mes.

Ø-CH2-O-C(=O)-O-N(H)-S(=O)2-Mes.

REFERENCE : TMS

SOLVENT : $CDCl_3$

CONC : ~10%

AMPLITUDE :

SPECTRUM : 13

INTEGRAL :

H_1 LEVEL : ✓

H_2 LEVEL :

GAIN : ✓

SWEEP WIDTH :

NOR ✓ SCALE EXP

10 PPM 600 500 400 300 200 100 0

SHIFT : 0

50Hz 0 50Hz 100Hz

SWEEP TIME :

300/150SEC SEC

DATE : 11/1/74

OPERATOR : R. Sommer

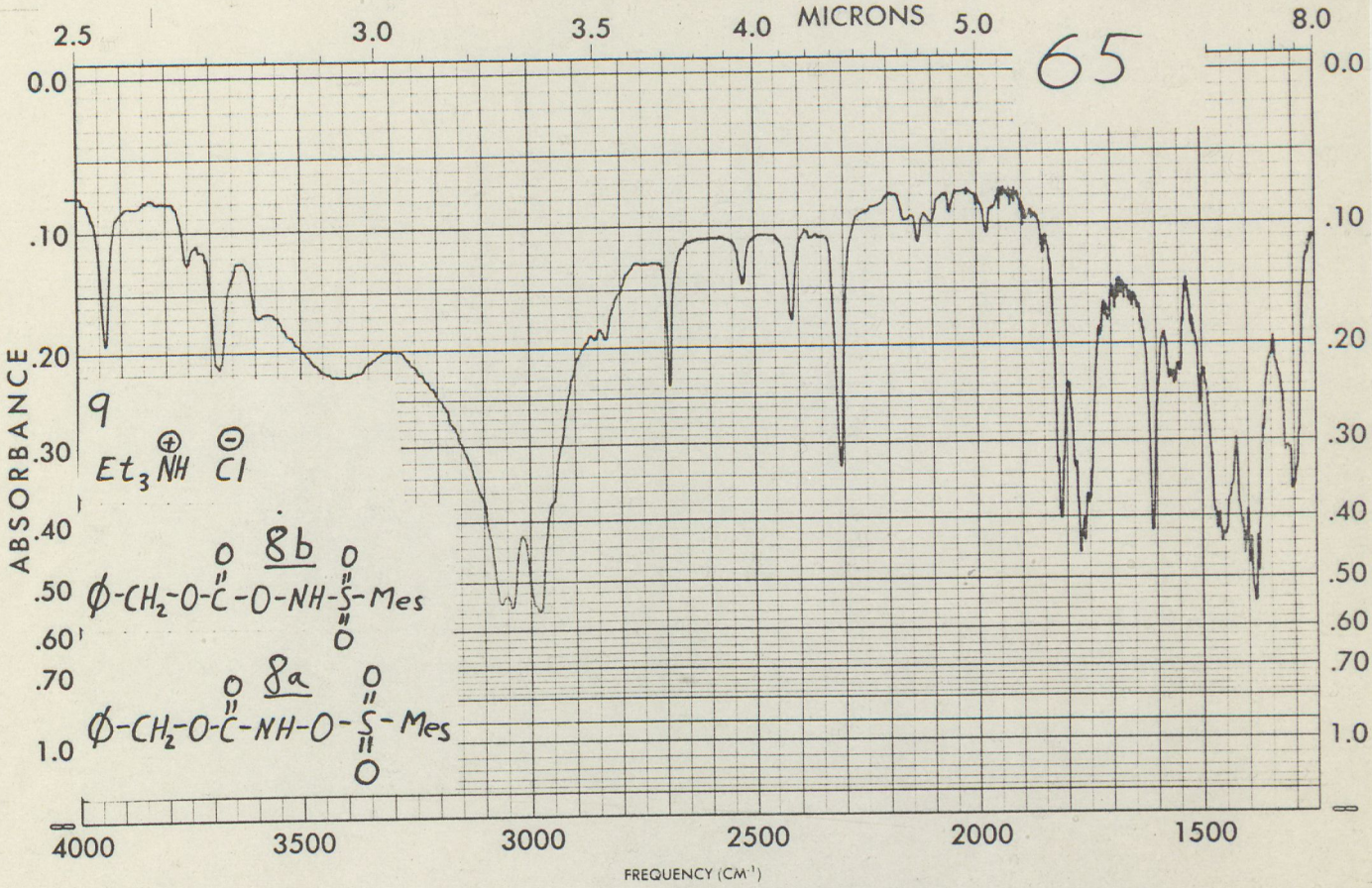
REMARKS :

64

HITACHI PERKIN ELMER

CHART NO. 435-7204

65



9

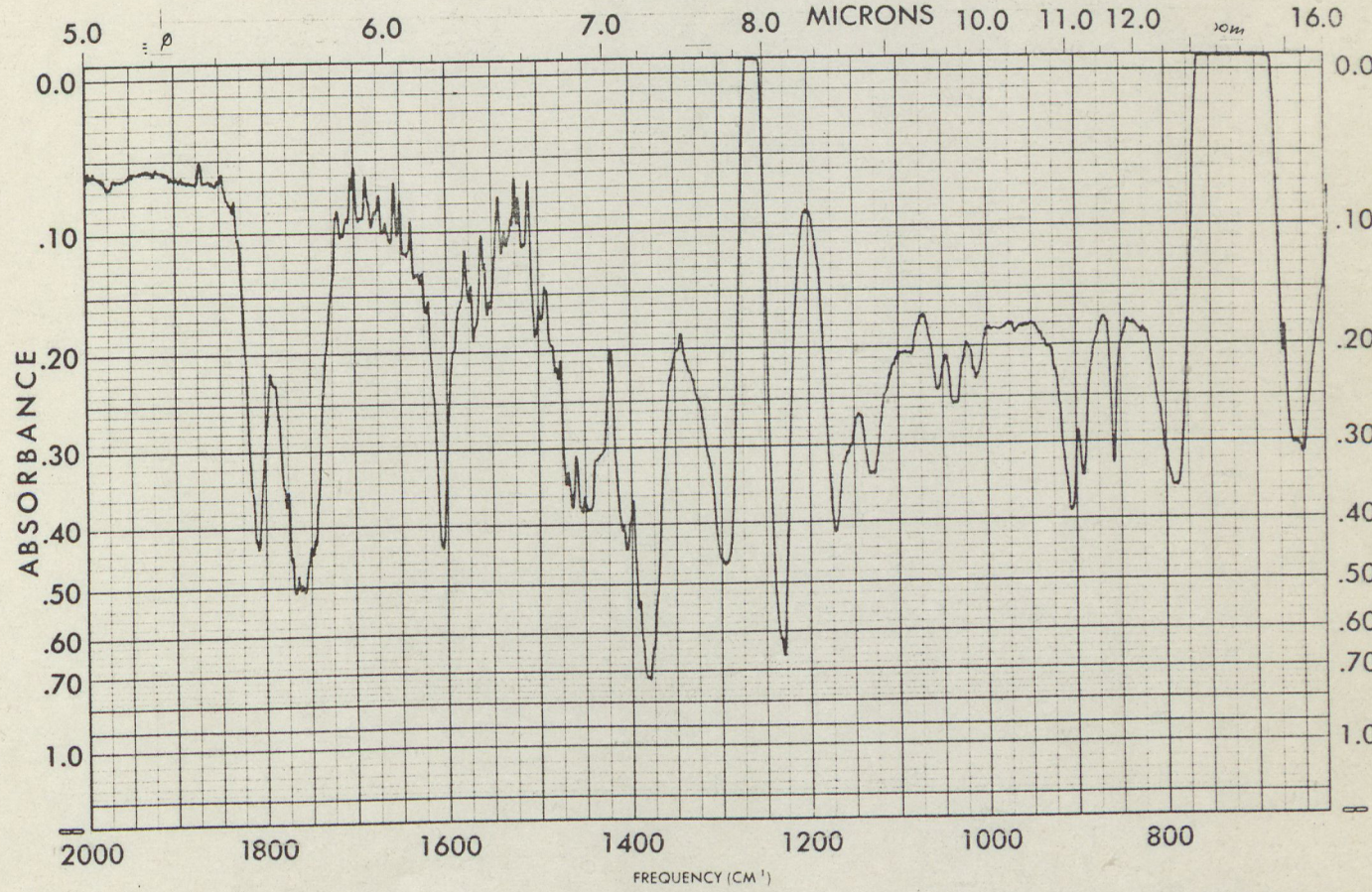
$Et_3\overset{\oplus}{N}H\ \overset{\ominus}{Cl}$

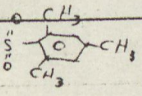
8b

$\phi\text{-}CH_2\text{-}O\text{-}\overset{O}{\overset{\|}{C}}\text{-}O\text{-}NH\text{-}\overset{O}{\overset{\|}{\underset{O}{\underset{\|}{S}}}}\text{-}Mes$

8a

$\phi\text{-}CH_2\text{-}O\text{-}\overset{O}{\overset{\|}{C}}\text{-}NH\text{-}O\text{-}\overset{O}{\overset{\|}{\underset{O}{\underset{\|}{S}}}}\text{-}Mes$



SAMPLE $\phi CH_2\text{-}O\text{-}\overset{O}{\overset{\|}{C}}\text{-}NH\text{-}O\overset{O}{\overset{\|}{\underset{O}{\underset{\|}{S}}}}$ 	CURVE NO.	SCAN SPEED FAST	OPERATOR Sample
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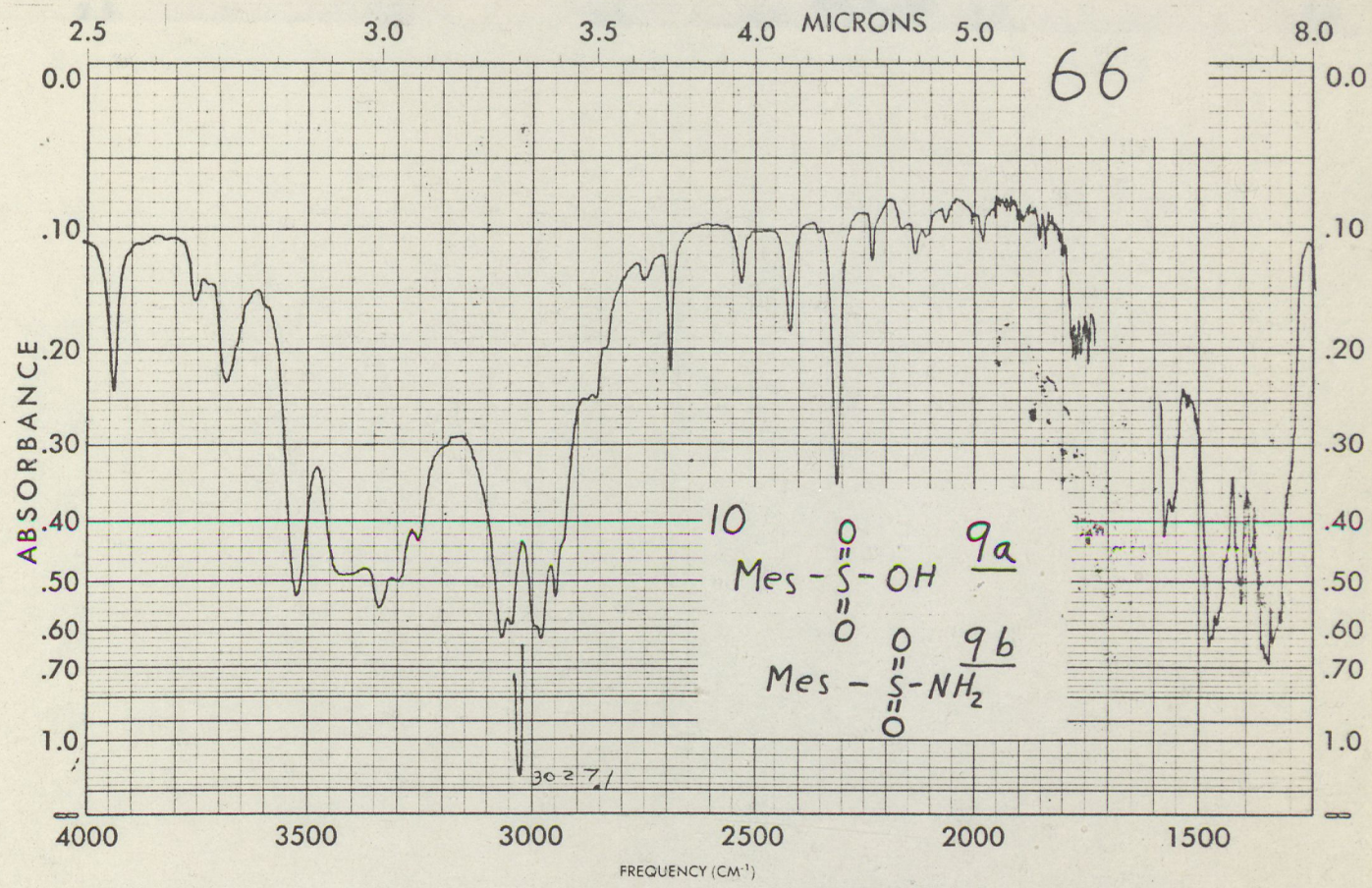
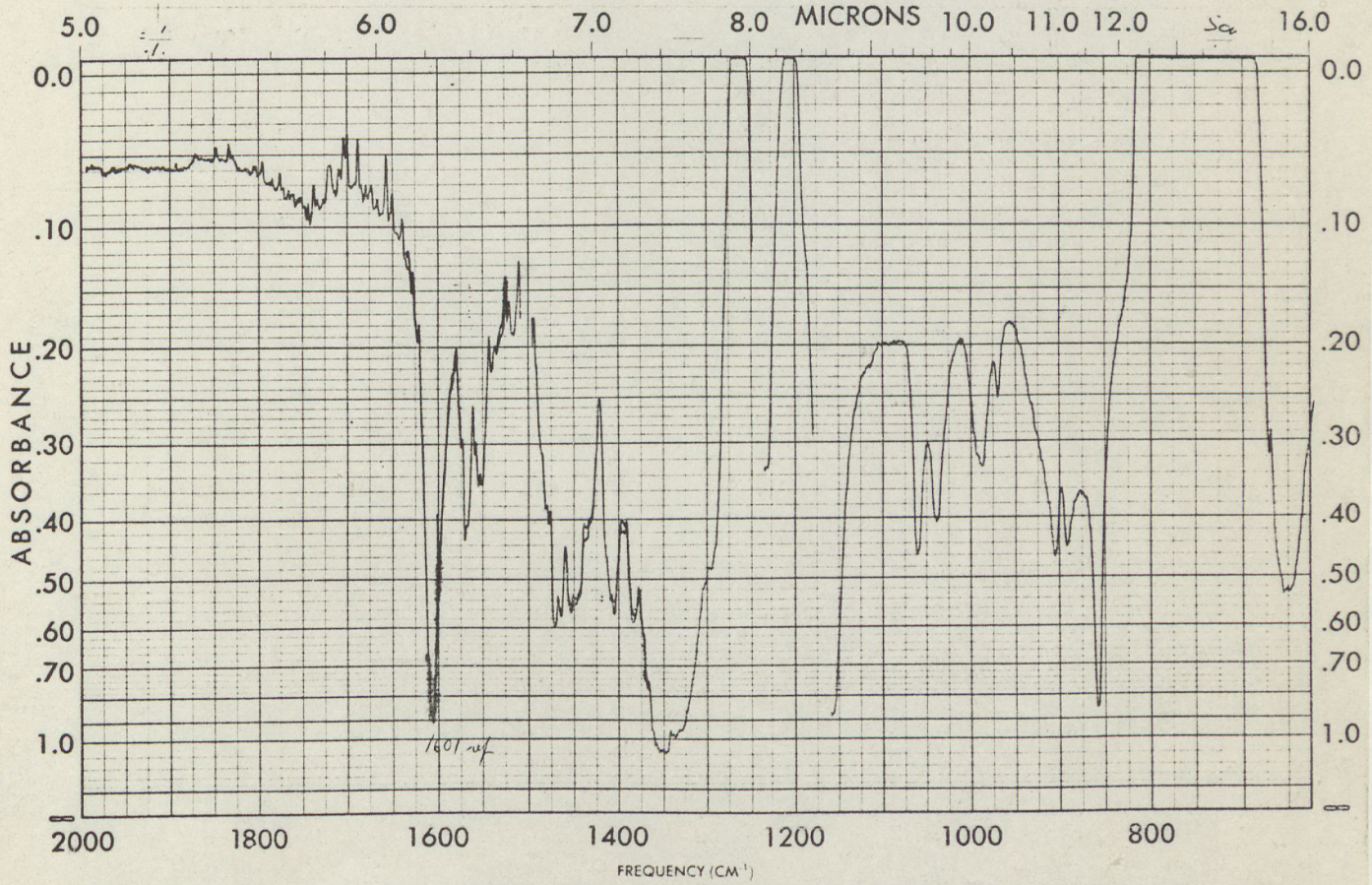
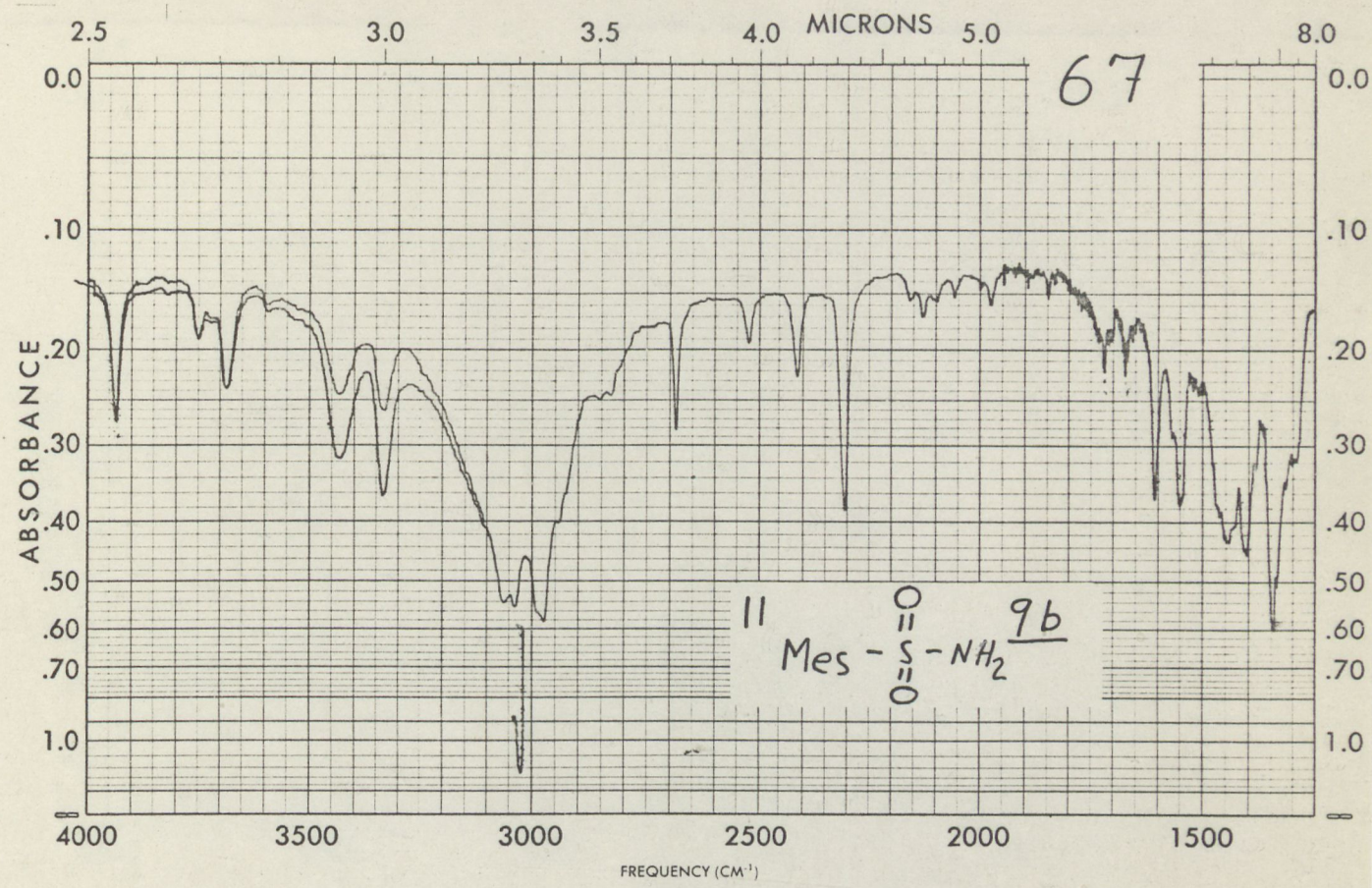
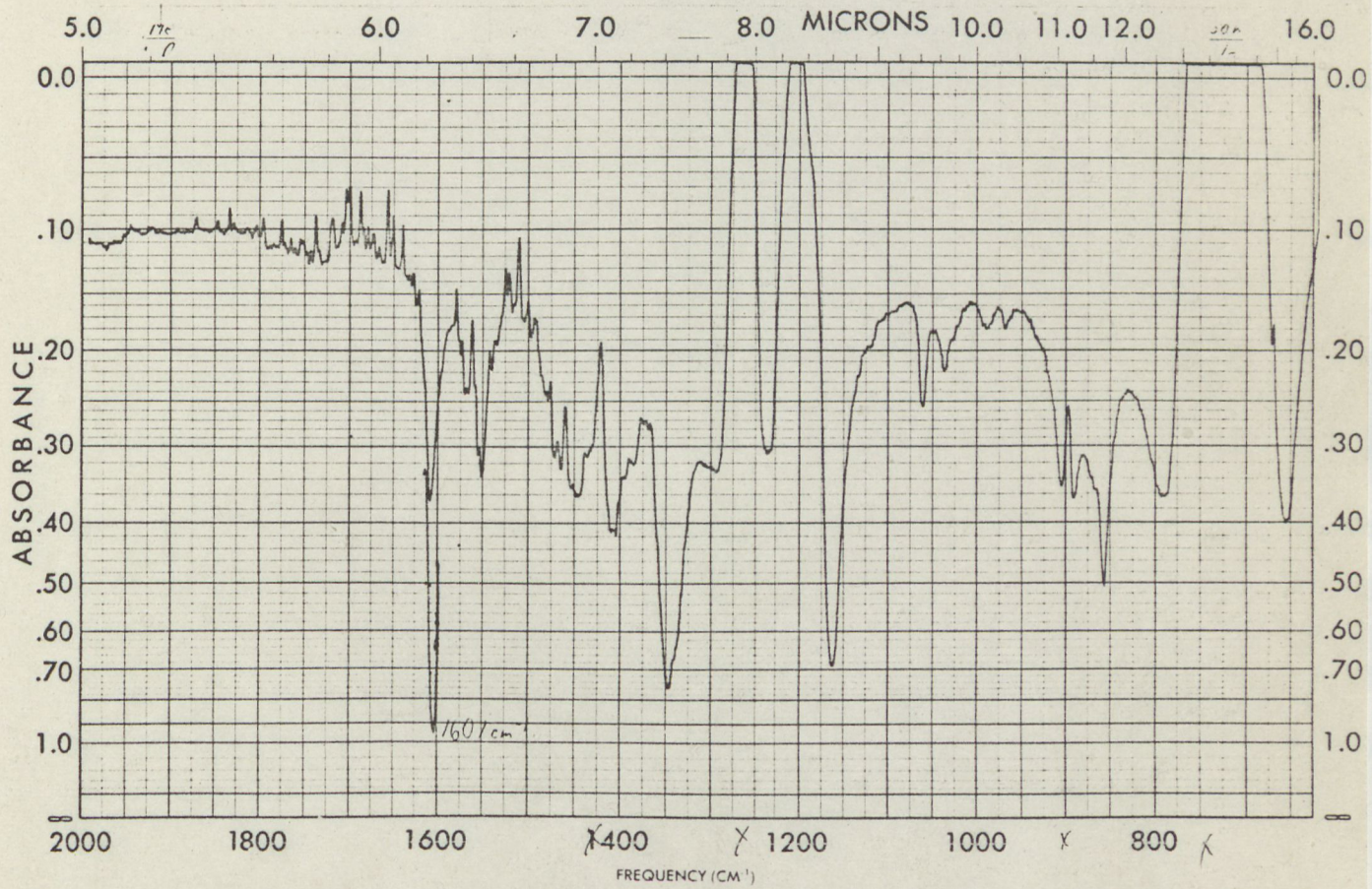
SOLVENT CH_2Cl_2	REFERENCE CH_2Cl_2		



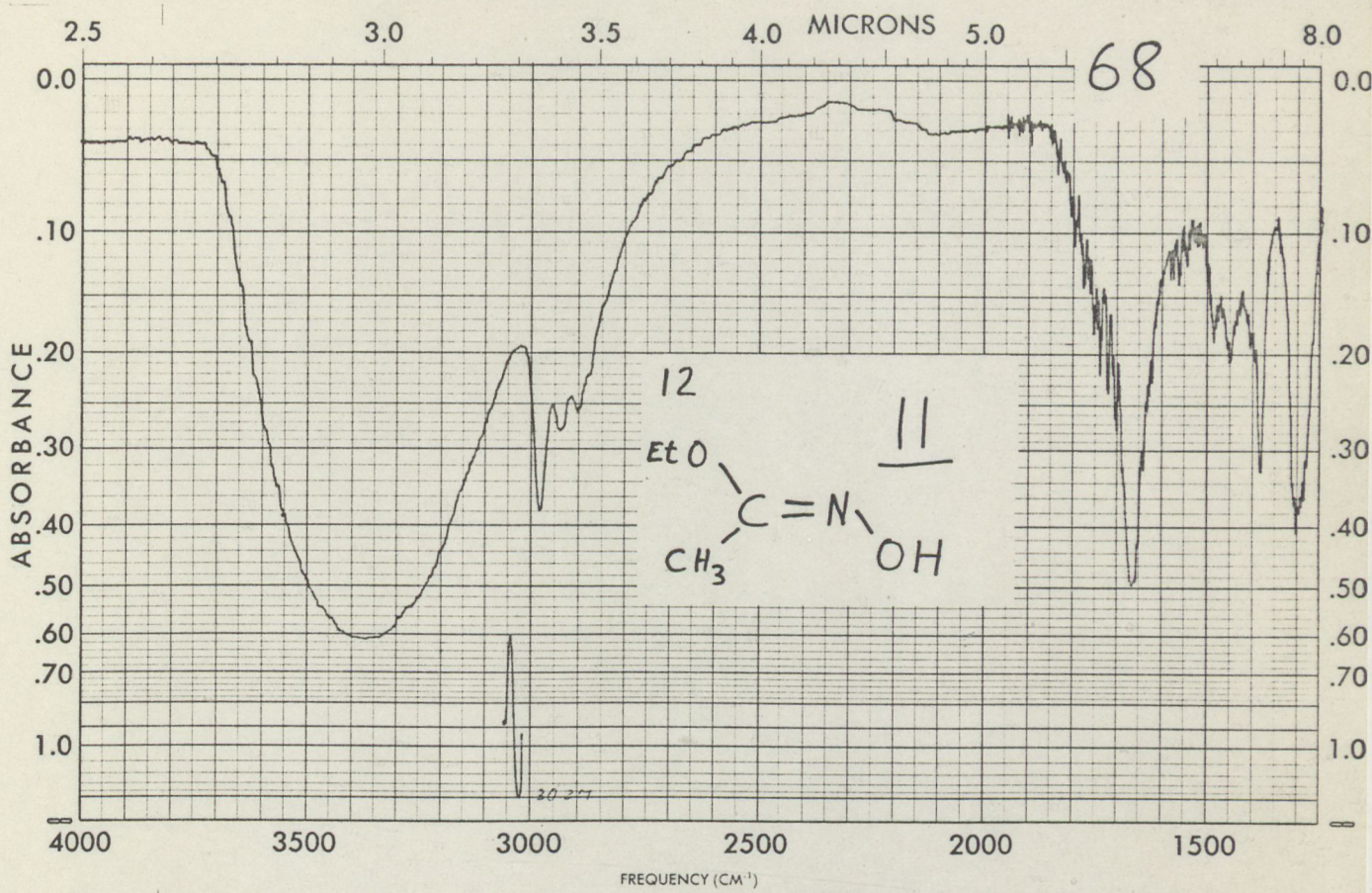


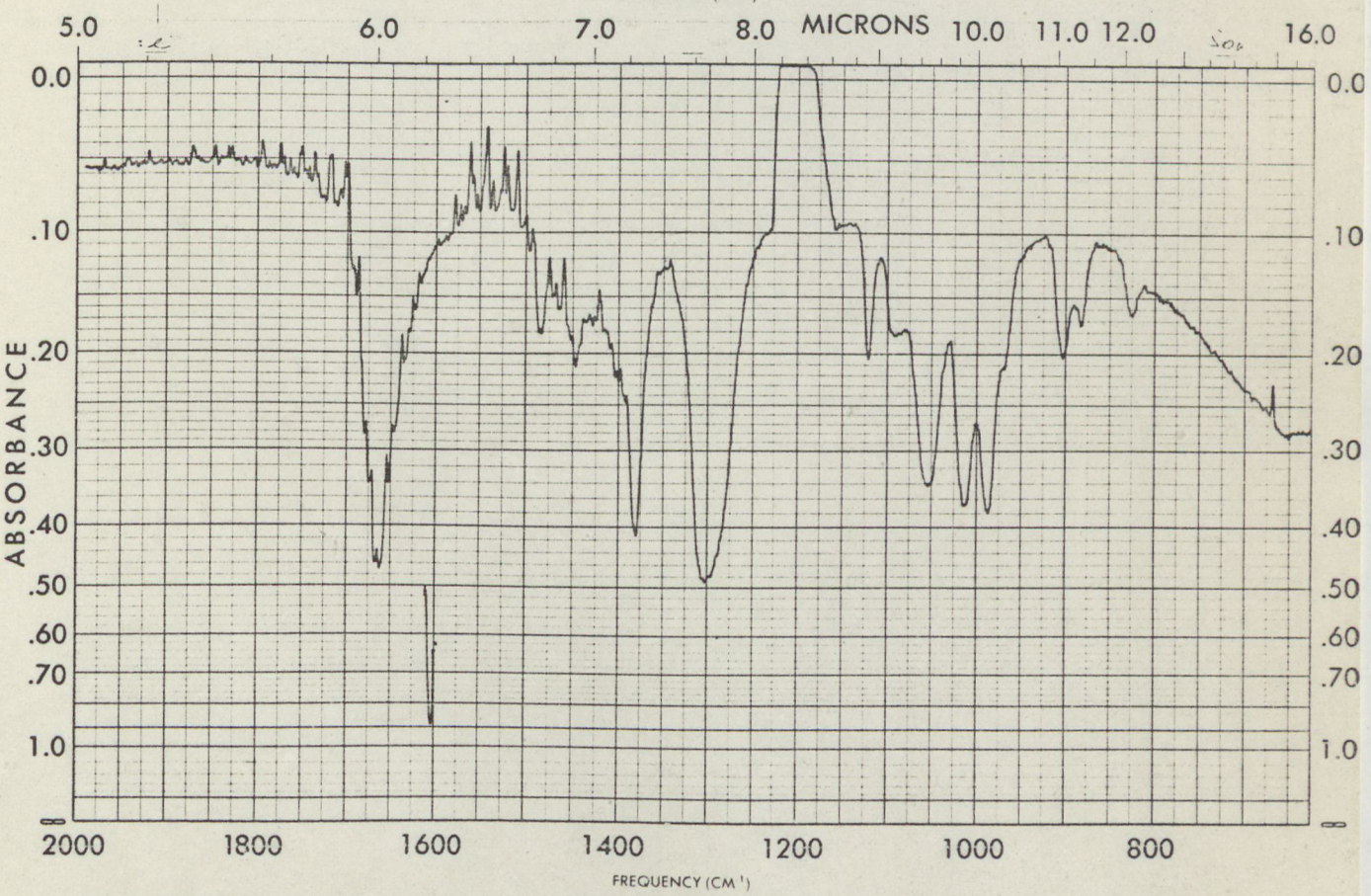
SAMPLE Hydrogenation Product 7/16/74	CURVE NO.	SCAN SPEED FAST	OPERATOR Sommer
ORIGIN	CONC. ~sat.	SLIT 30	DATE 7/17/74
SOLVENT CH_2Cl_2	CELL PATH 0.1mm	REMARKS Tab. Peaks: 1604, 1350, 1165, 1060, 1040	
	REFERENCE CH_2Cl_2		



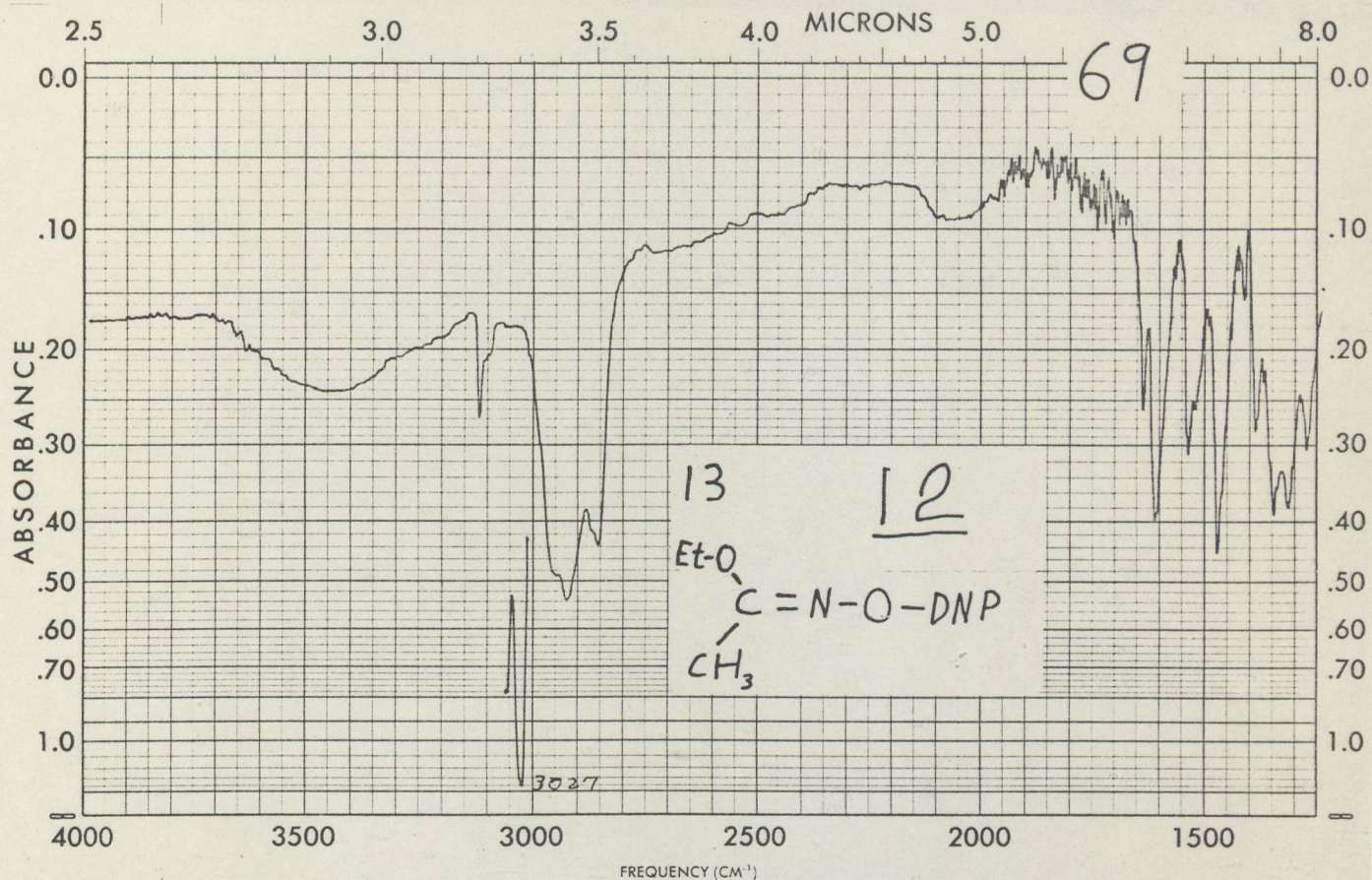


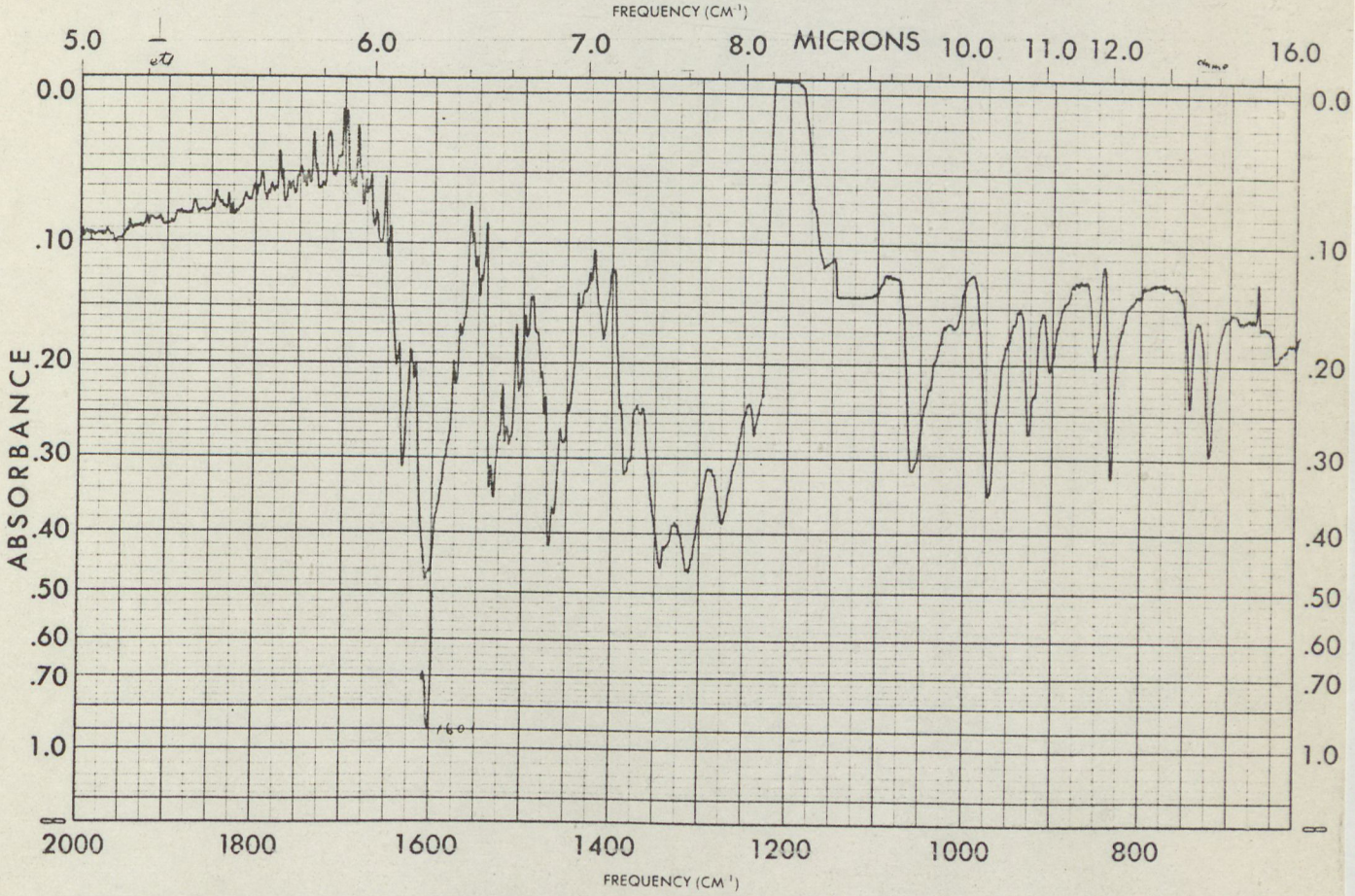
SAMPLE Mesitylene Sulfonamide MP 141.5 - 143 °C	CURVE NO.	SCAN SPEED FAST	OPERATOR Sommer
ORIGIN 7/19/74	CONC.	SLIT 30	DATE 7/23/74
SOLVENT CH_2Cl_2	CELL PATH 0.1 mm.	REMARKS	
	REFERENCE CH_2Cl_2		



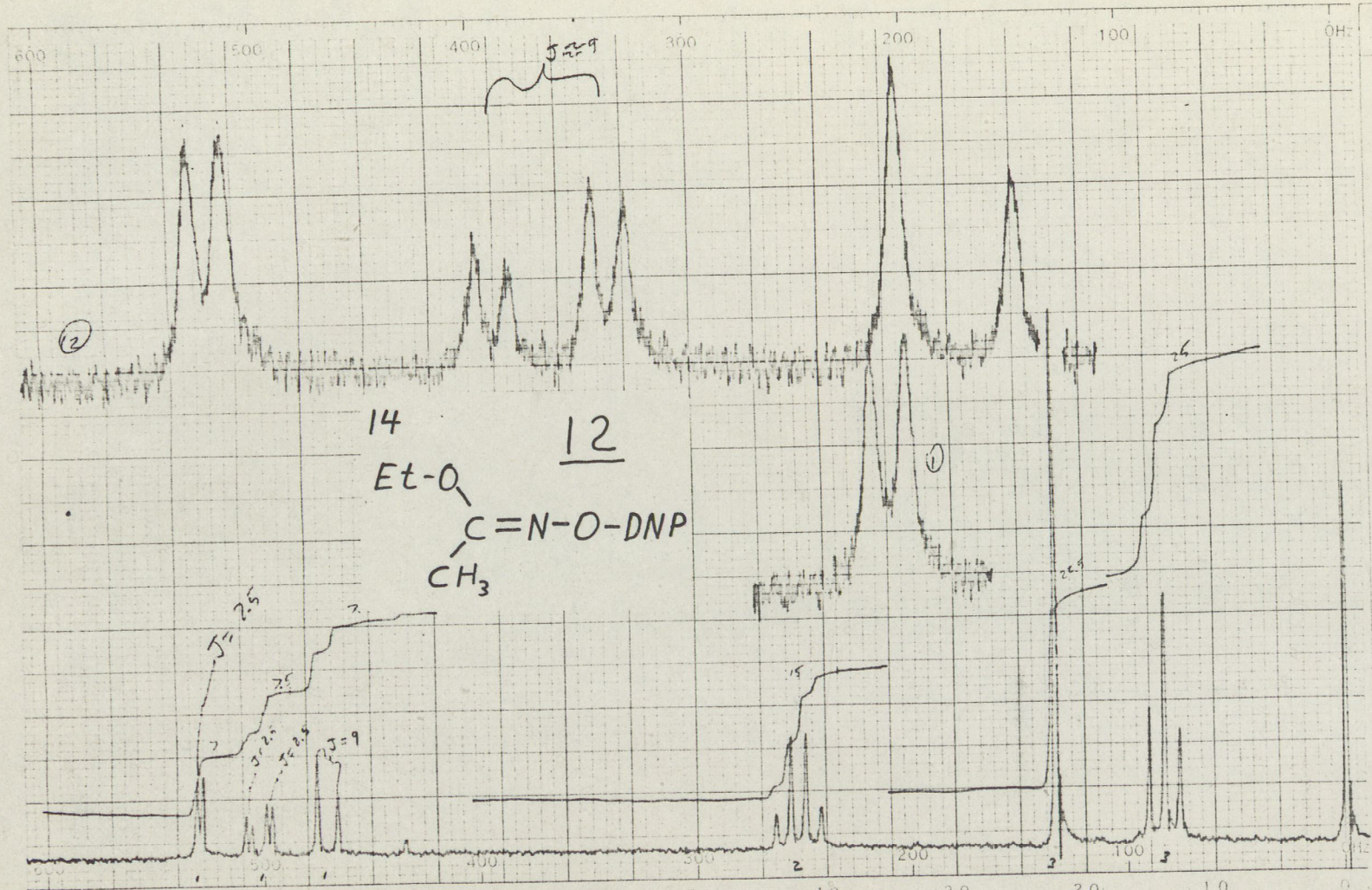


SAMPLE Ethyl acetohydroximate	CURVE NO.	SCAN SPEED FAST	OPERATOR Sommer
ORIGIN 7/26/74	CONC. ~~5%~~ 100%	SLIT 30	DATE 7/26/74
SOLVENT CCl4	CELL PATH Thin film	REMARKS	
	REFERENCE Air		



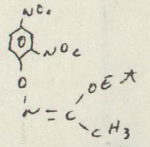


SAMPLE ethyl O-(2,4-dinitrophenyl)acetohydroxamate	CURVE NO.	SCAN SPEED FAST	OPERATOR Simmons
ORIGIN 8/5/74	CONC.	SLIT 30	DATE 9/6/74
SOLVENT nujol	CELL PATH Thin film	REMARKS	
	REFERENCE air		



'H SPECTRUM NO.: 1

SAMPLE: Et-O-(2,4-dinitrophenyl)-methylhydroxamate

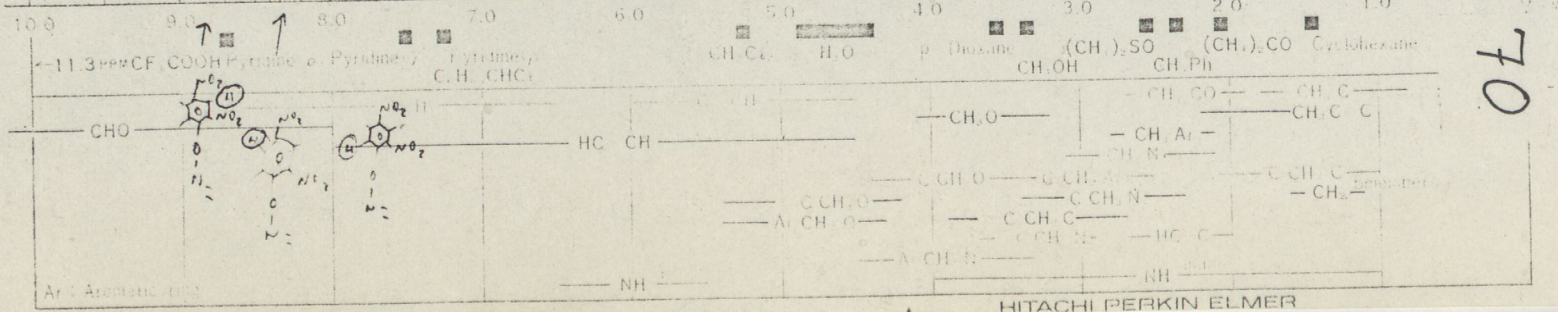


REFERENCE: TMS
SOLVENT: $CDCl_3$
CONC: ~10%
AMPLITUDE: 10
SPECTRUM: 10
INTEGRAL:

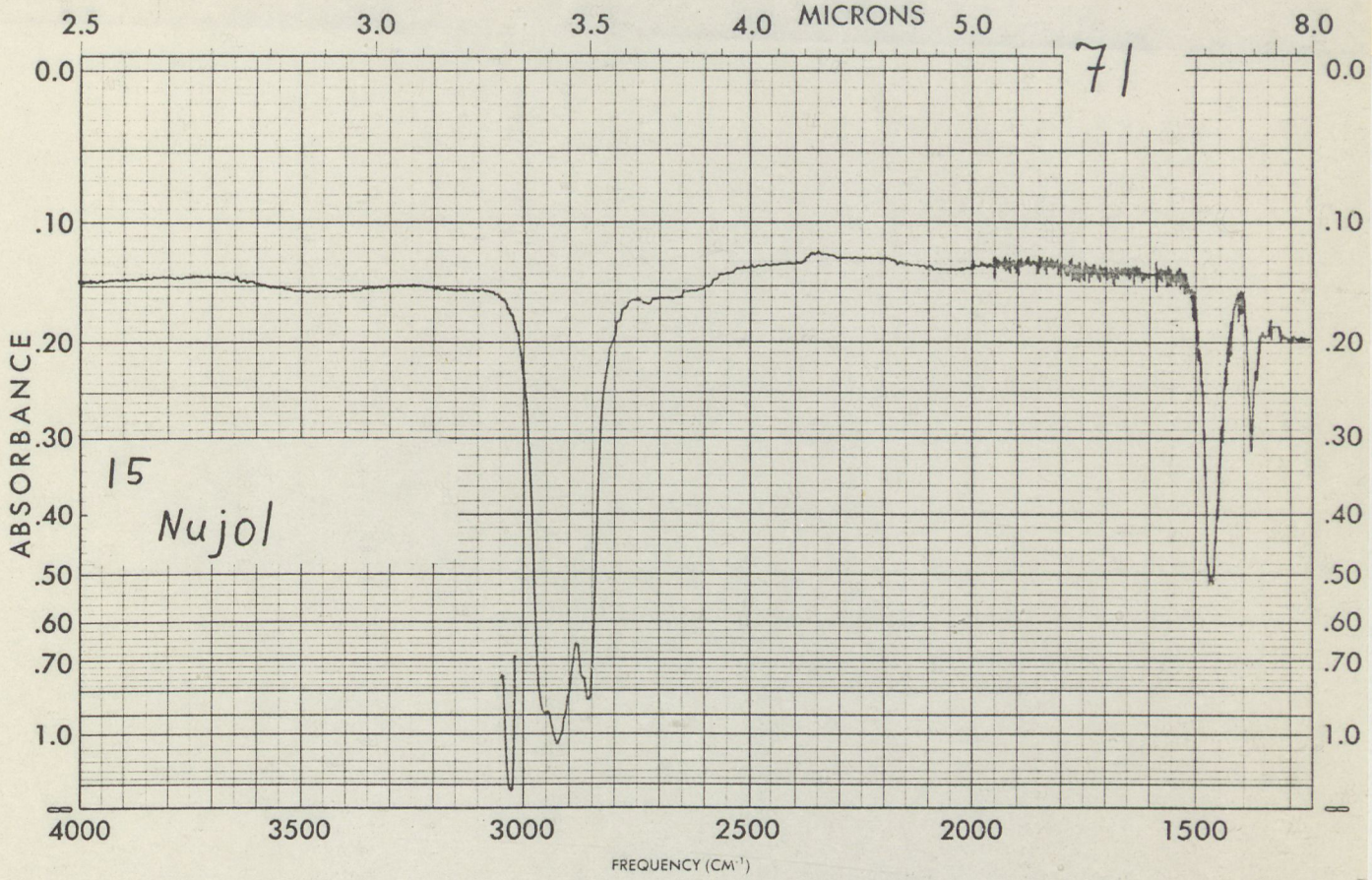
H_1 LEVEL:
H_2 LEVEL:
GAIN:
SWEEP WIDTH:
SHIFT:
SWEEP TIME: 300/150SEC SEC
DATE: 9/26/74
OPERATOR: Sommer

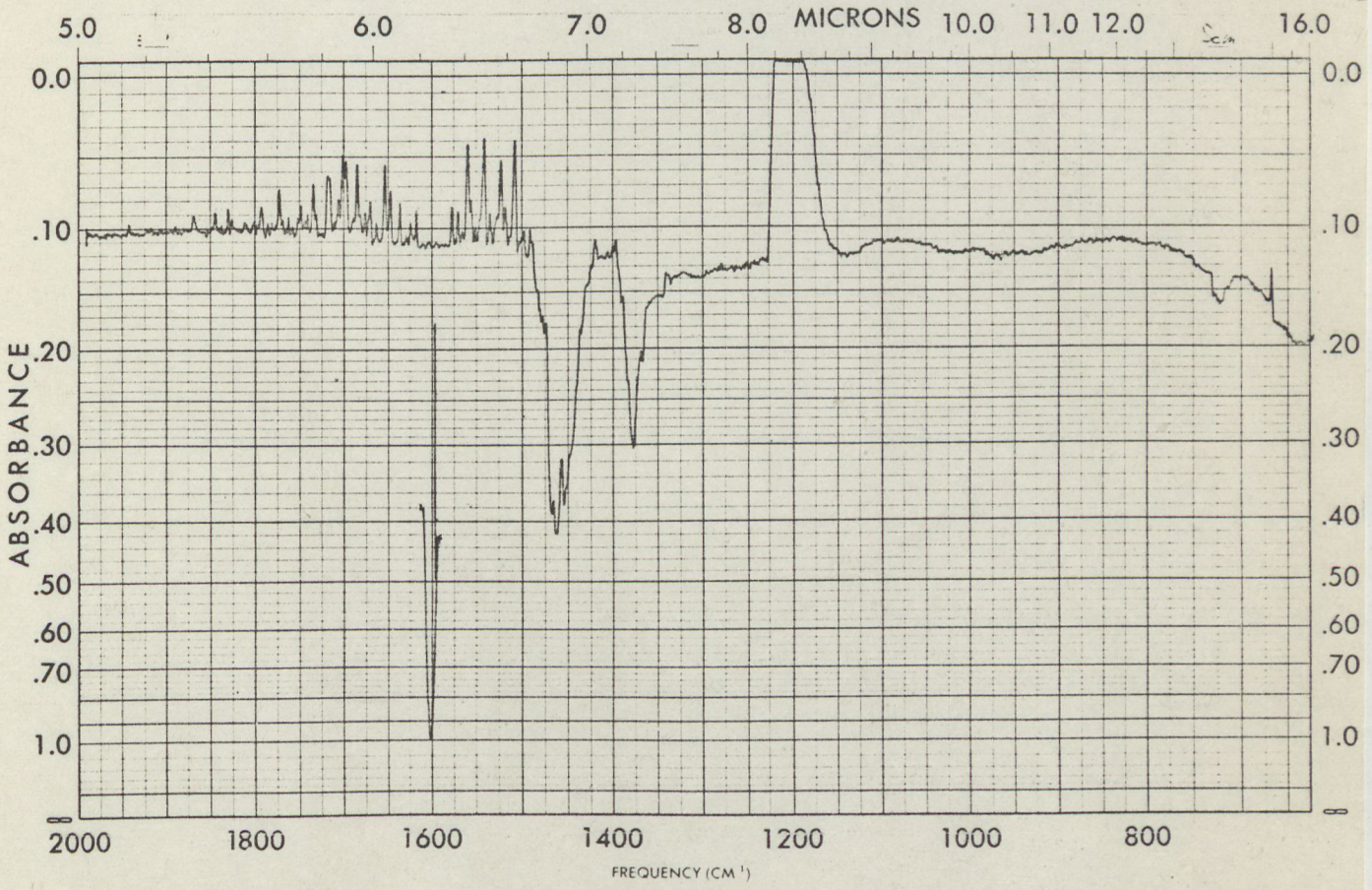
REMARKS:
① 500-600 cps Amp = 15
② 500-600 cps 50 ← Amp = 15 Sweeping 450-550 cps

Spectrum is 1st order
2 AMX System between 7.7 & 8.7 ppm.

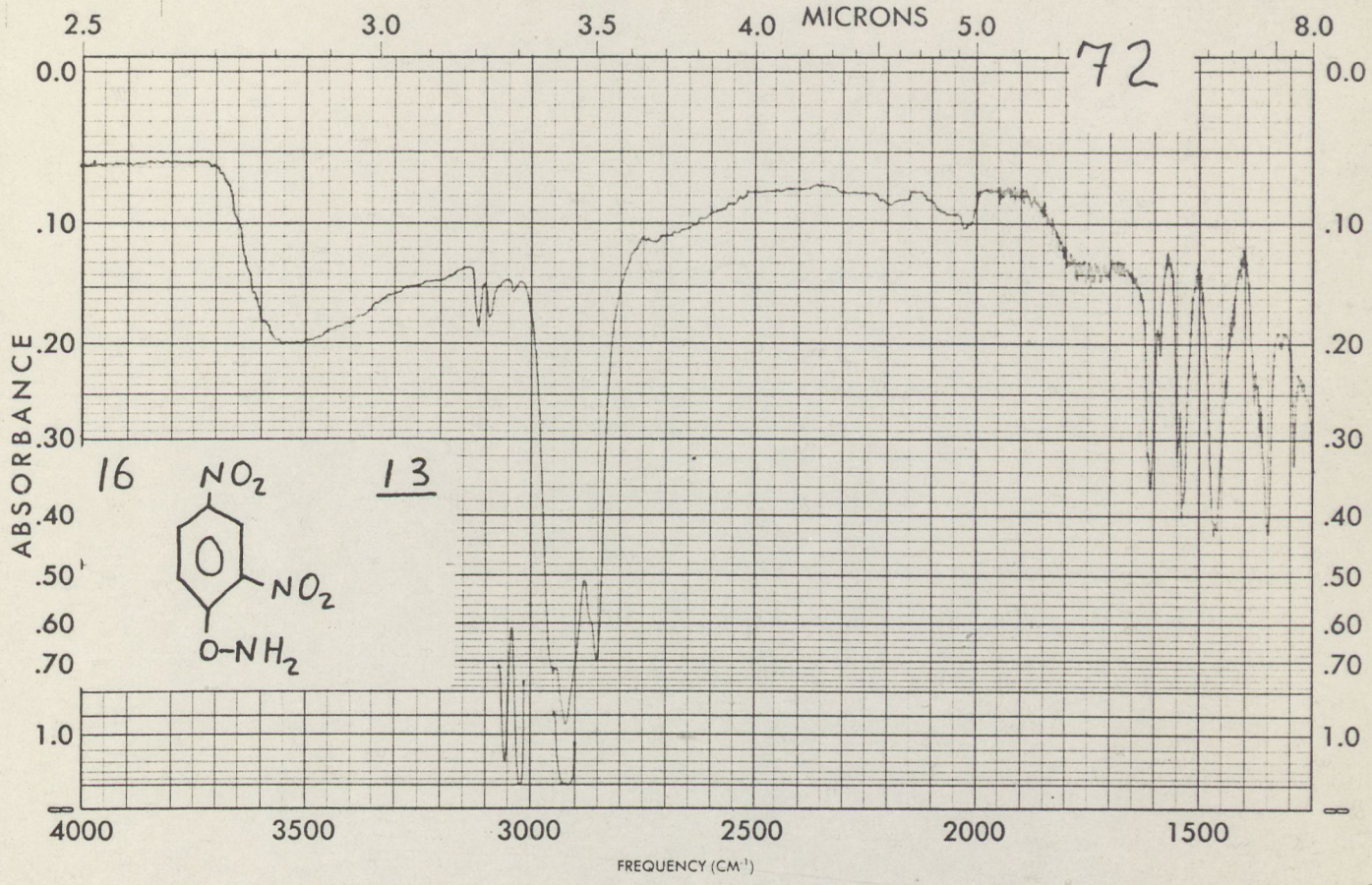


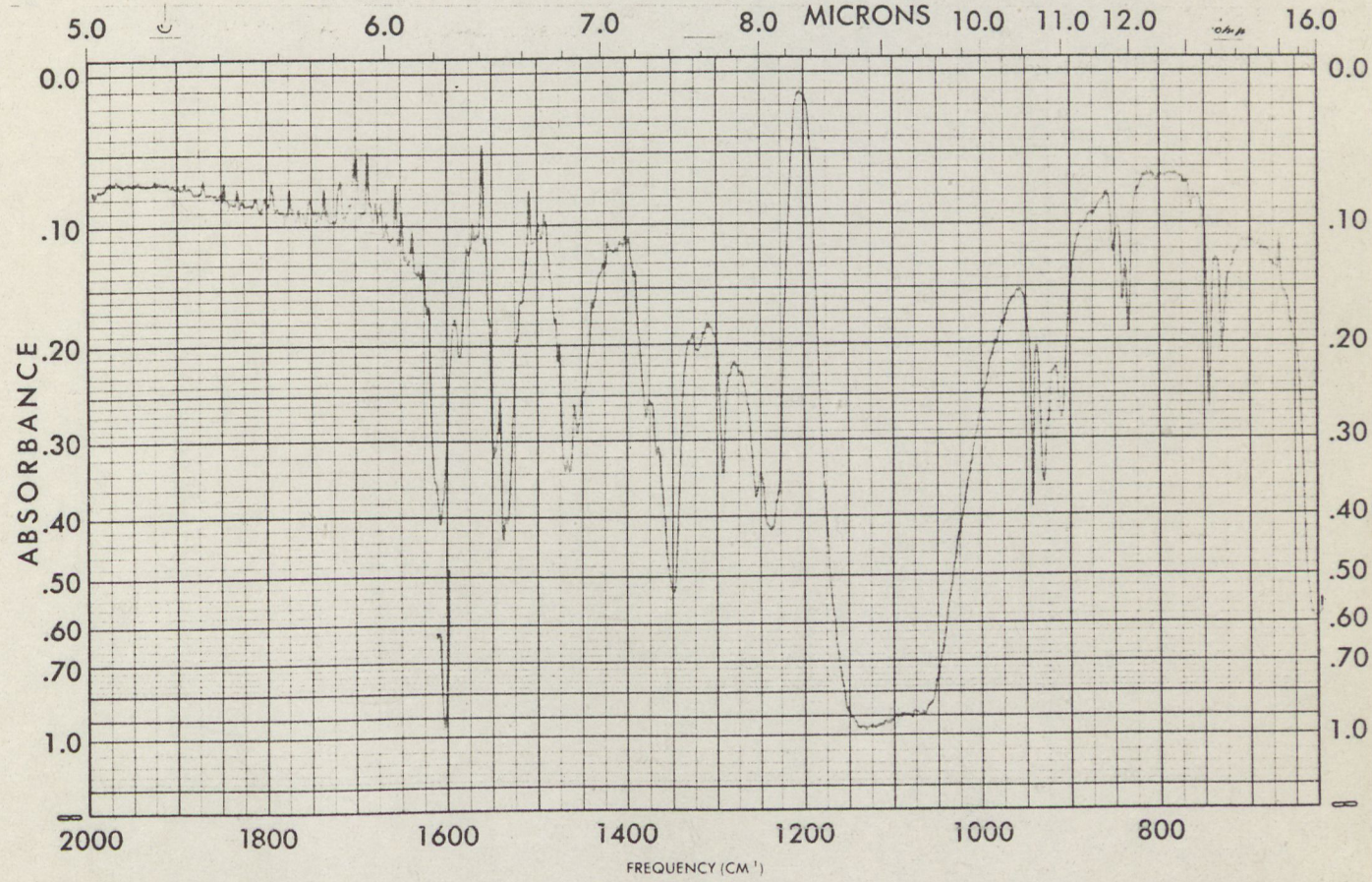
70



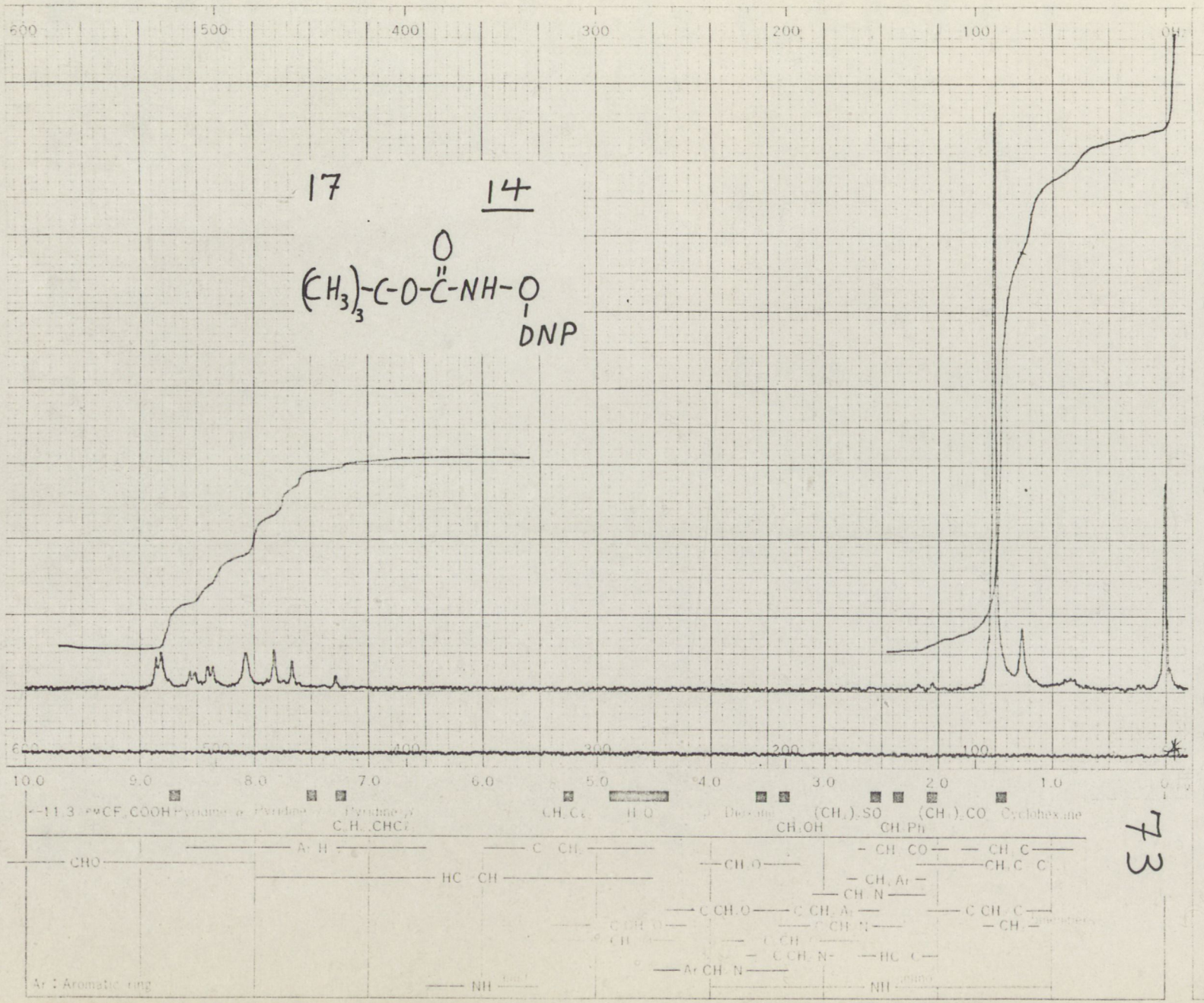


SAMPLE nujol	CURVE NO.	SCAN SPEED FAST	OPERATOR Sommer
	CONC. 100%	SLIT 3.0	DATE
ORIGIN	CELL PATH Thin Film	REMARKS	
SOLVENT neat	REFERENCE Air		



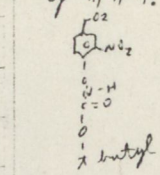


SAMPLE O-(2,4-dinitrophenyl)-hydroxylamine	CURVE NO.	SCAN SPEED FAST	OPERATOR Sommer
ORIGIN Clearage 8/15/74 (2)	CONC.	SLIT 30	DATE 8/15/74
SOLVENT Nujol	CELL PATH thin film	REMARKS	
	REFERENCE air		



^{1}H SPECTRUM NO. : 8

SAMPLE : Recrystd from R.M.V of 11/4/74.



REFERENCE :
SOLVENT :
CONC : 5-10 %

AMPLITUDE :
SPECTRUM : 9
INTEGRAL : 11

H$_1$ LEVEL :

H$_2$ LEVEL :
GAIN :

SWEEP WIDTH :

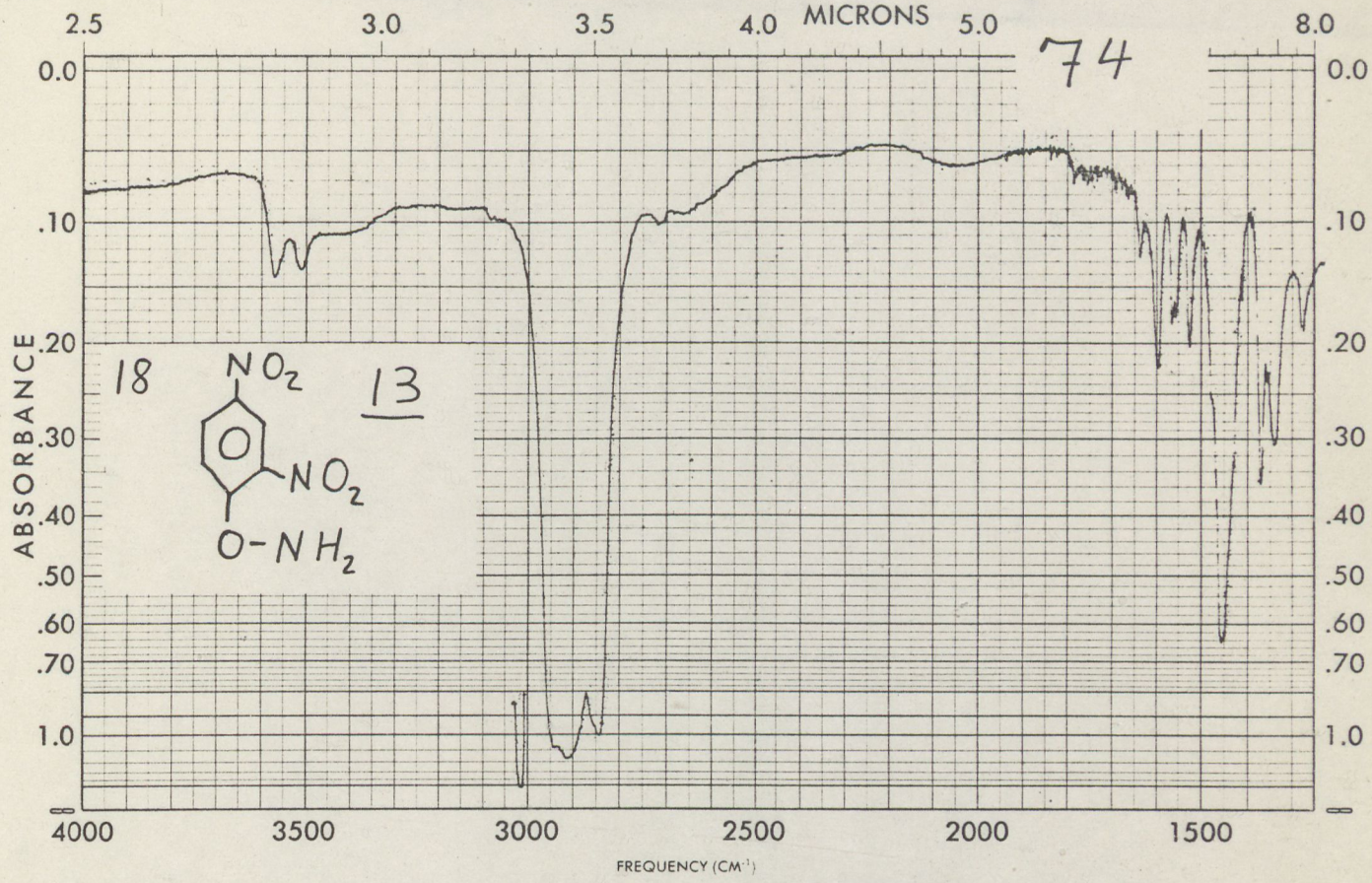
SHIFT :

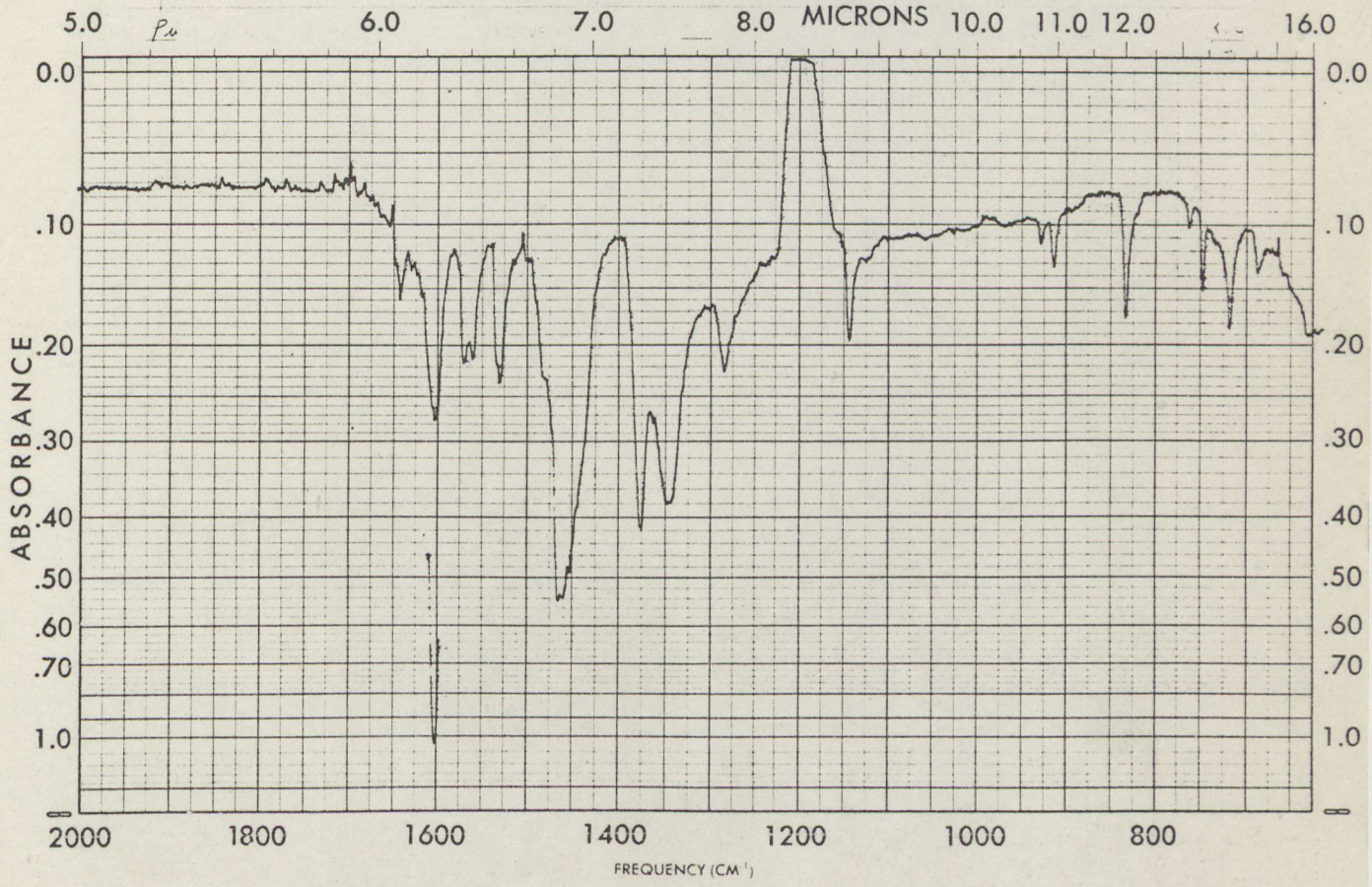
SWEEP TIME :
✓ 300/150SEC

DATE : 11/11/74

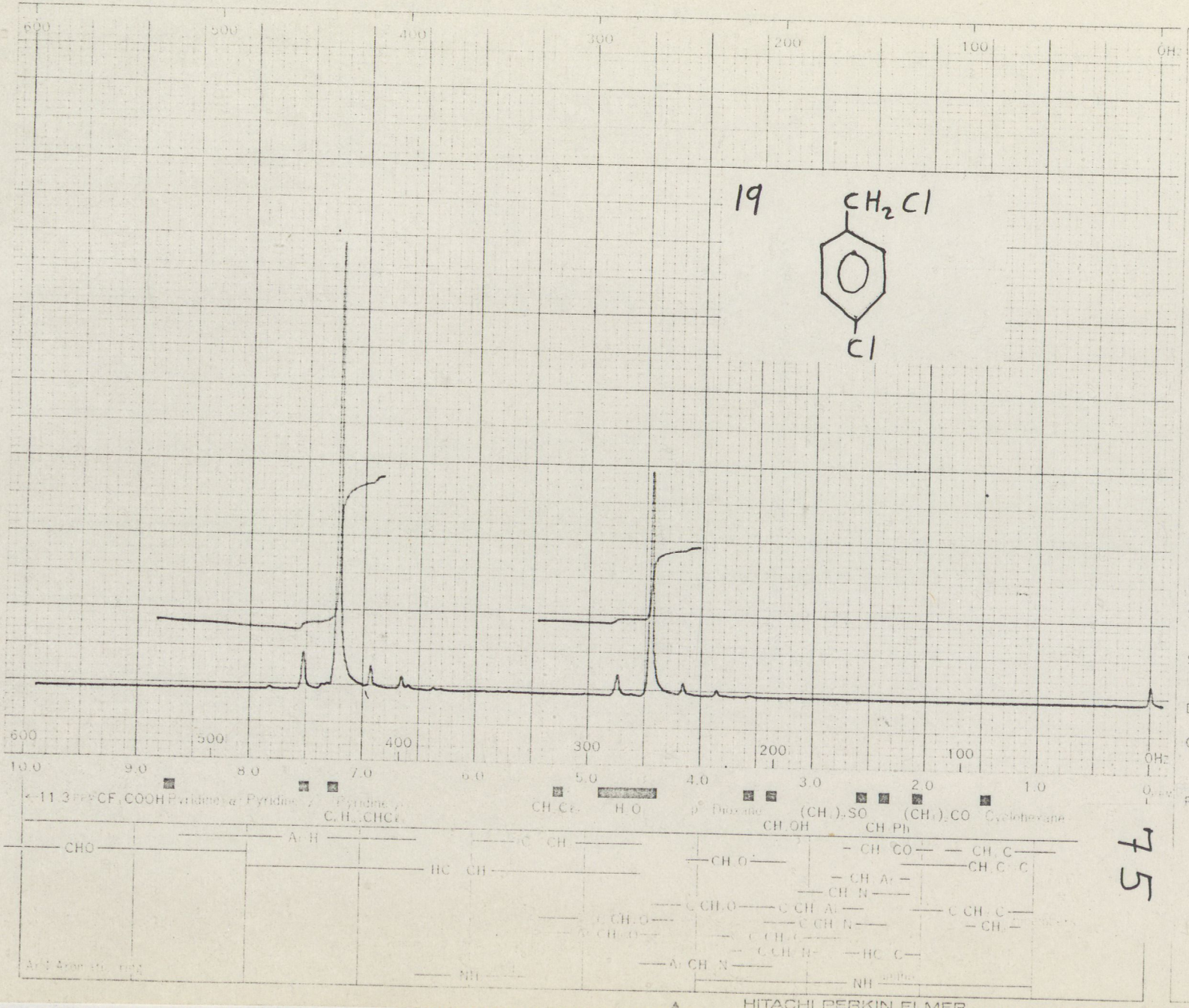
OPERATOR : R. Sommer

REMARKS :
* 20-10 ppm



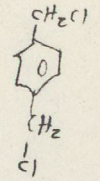


SAMPLE Purification prod of 12-2-74 c.t. 3-6	CURVE NO.	SCAN SPEED FAST	OPERATOR R. Sweeney
ORIGIN Cleavage 11/12/74	CONC. ?	SLIT 30	DATE 12/13/74
SOLVENT Nujol	CELL PATH thin film	REMARKS Prot	
	REFERENCE air		



H SPECTRUM NO. : 25

SAMPLE :



REFERENCE : TMS
SOLVENT : $CDCl_3$
CONC : ~50%

AMPLITUDE :
SPECTRUM : 5
INTEGRAL : 5

H_1 LEVEL : ✓

H_2 LEVEL :
GAIN : ✓

SWEEP WIDTH : ✓

SHIFT :

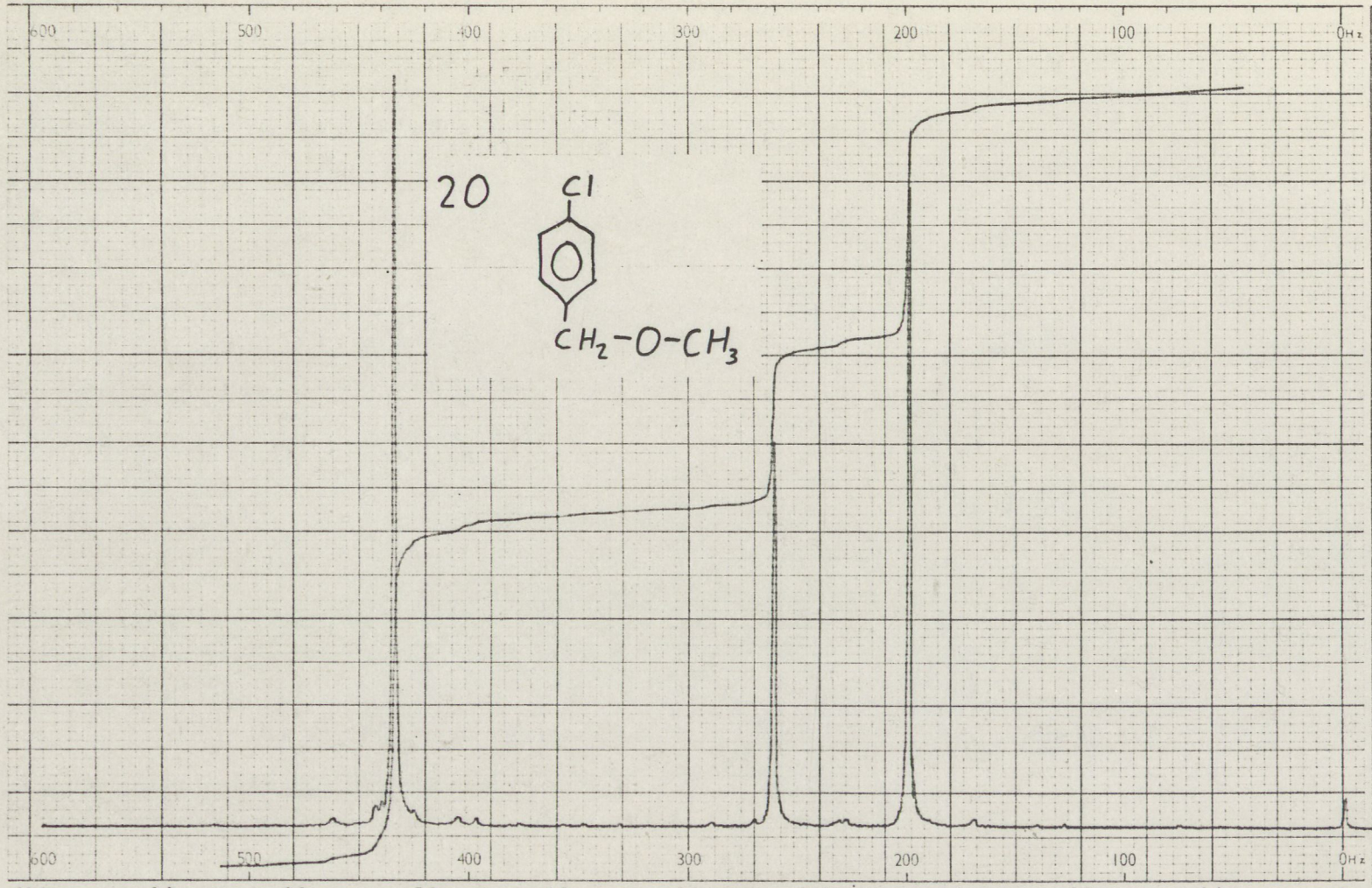
SWEEP TIME :
✓ 300 150SEC SEC

DATE : 1/24/75

OPERATOR : R. Somers

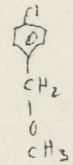
REMARKS :

47



1H SPECTRUM NO.: 34

SAMPLE:



Reaction begun on 2/6/75

REFFERENCE: TMS

SOLVENT: $CDCl_3$

CONC: 10-20%

AMPLITUDE:

SPECTRUM 6

INTEGRAL 7

H1 LEVEL: HI | NOR | LO

H2 LEVEL:

GAIN: NOR | X10

SWEEP WIDTH:

NOR SCALE EXP.

10PPM 600 500 400 300 200 100 0

SHIFT

50Hz | 600Hz | 600Hz

SWEEP TIME

☑ 300/150 SEC ☐ / SEC

DATE: 2/10/75

OPERATOR R. Sommer

REMARKS:

Ratio ≈ 4:2:3

94

Ar: Aromatic ring

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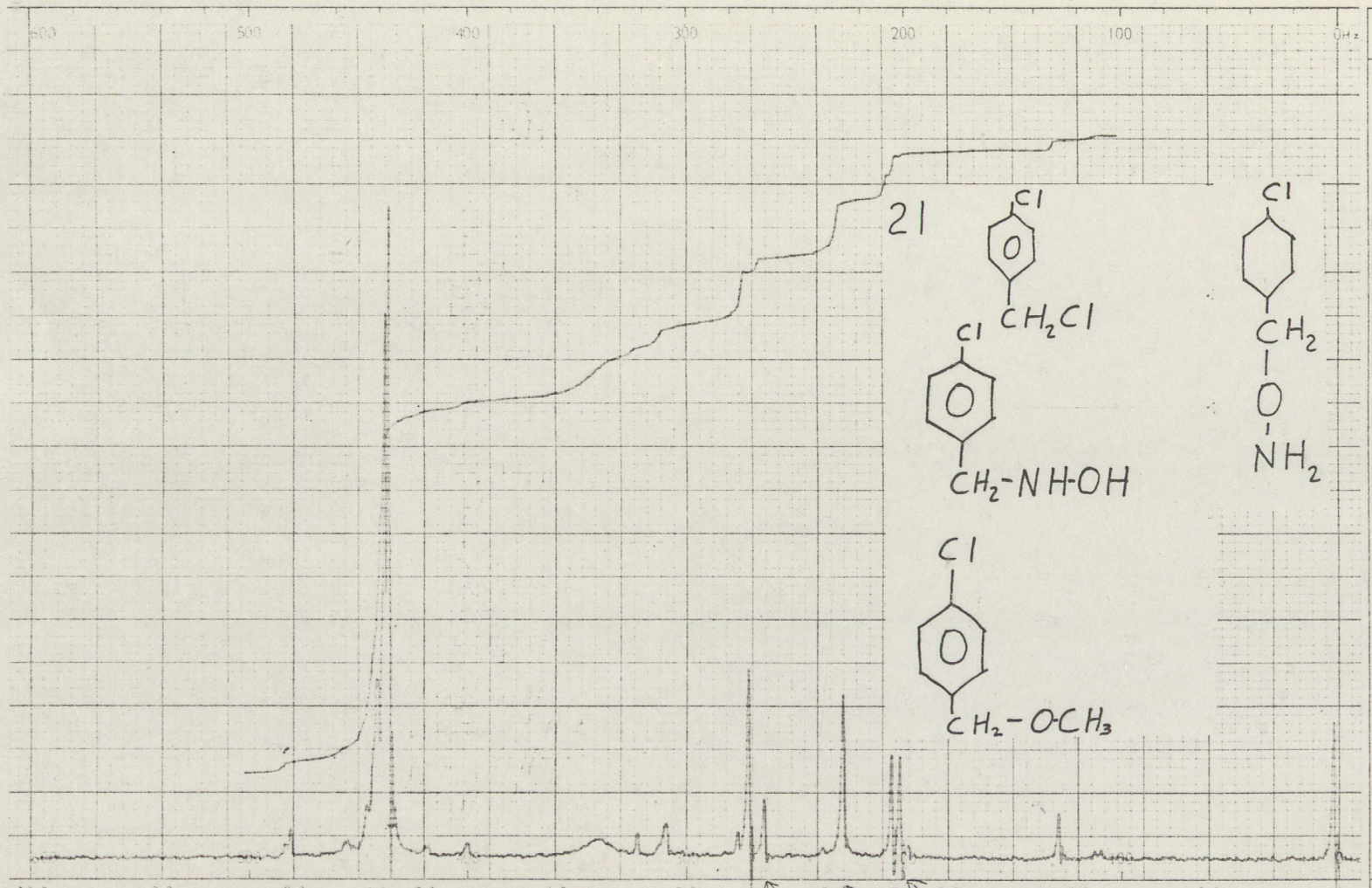


1H SPECTRUM NO.: 26

SAMPLE: prod of 1/24/75

REFFERENCE: TMS
SOLVENT: CDCl3
CONC: ?
AMPLITUDE:
SPECTRUM 9
INTEGRAL 9

H1 LEVEL:

H2 LEVEL:

GAIN: X ✓ X10

SWEEP WIDTH:
NOR ✓ SCALE EXP.
10 PPM 600 500 400 300 200 100 0

SHIFT

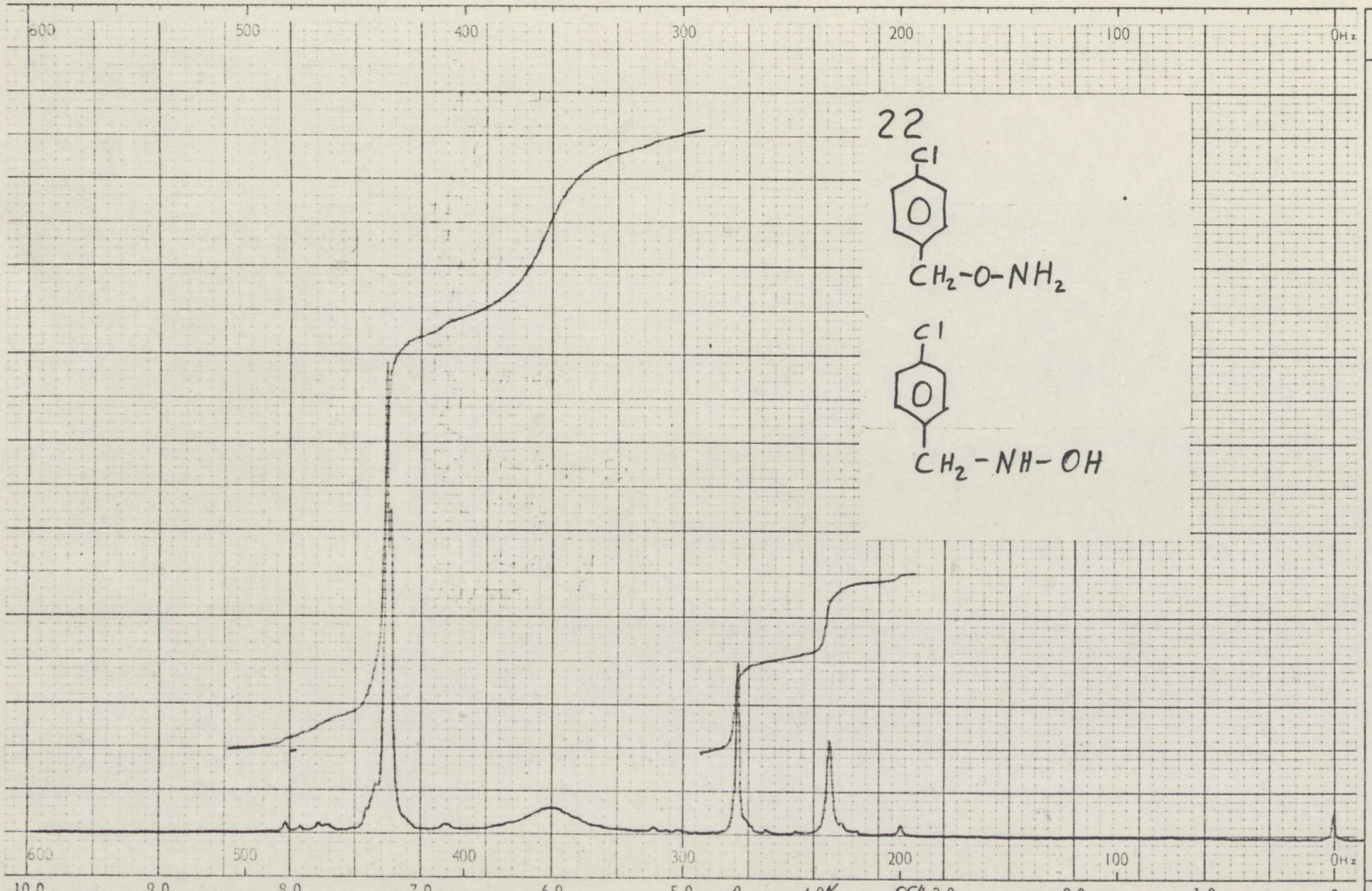
SWEEP TIME
☑ 300/150 SEC ☐ / SEC

DATE: 1/31/75

OPERATOR R. Sommer

REMARKS:
MeOH is present - solvent not totally removed.
$CH_3\overset{O}{\overset{\|}{C}}CH_3$ was used to remove the NMR fade. Ca 2.15 δ.

HITACHI PERKIN ELMER



1H SPECTRUM NO.: 27

SAMPLE: Prod of 1/31/75 RXN after extraction & purification

REFFERENCE: TMS

SOLVENT: CDCl3

CONC: ?

AMPLITUDE:

SPECTRUM 5

INTEGRAL 6

H1 LEVEL: ☑ NOR LO

H2 LEVEL:

GAIN: ☑ X10

SWEEP WIDTH: ☑ NOR SCALE EXP.

10PPM 600 500 400 300 200 100 0

SHIFT ← 50Hz ← 600Hz → 600Hz

SWEEP TIME ☑ 300/150 SEC ☐ / SEC

DATE: 2/3/75

OPERATOR R. Sommer

REMARKS:

5 : 4

0 : N

87

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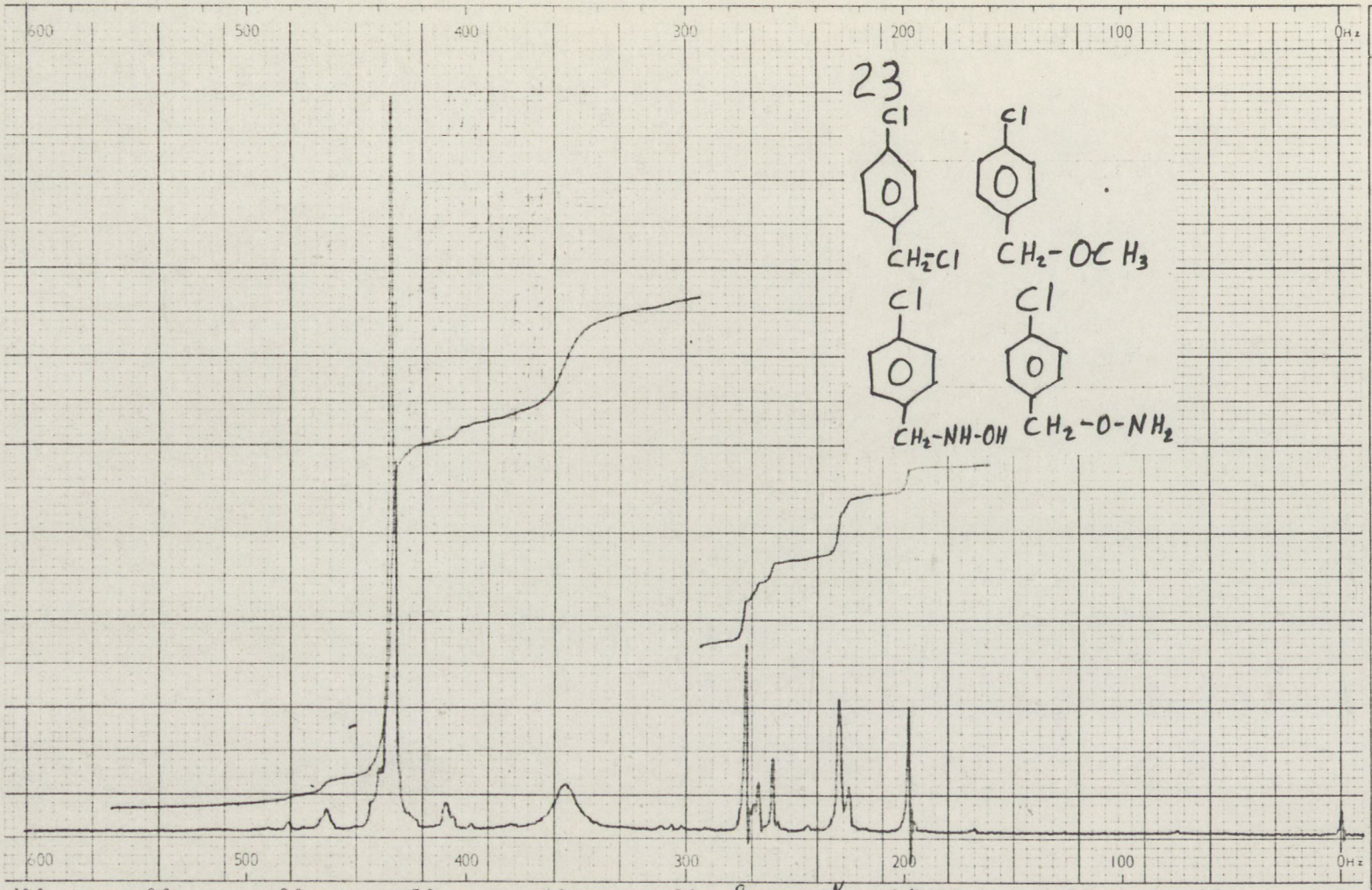
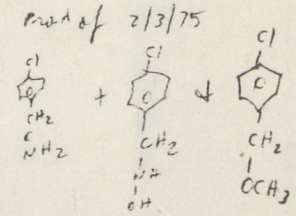


1H SPECTRUM NO.: 28

SAMPLE: Prod of 2/3/75



REFFERENCE: TMS

SOLVENT: $CDCl_3$

CONC: ?

AMPLITUDE:

SPECTRUM 6

INTEGRAL 6

H1 LEVEL: HI | NOR ✓ | LO

H2 LEVEL:

GAIN: ✓ | x10

SWEEP WIDTH: NOR ✓ SCALE EXP.

10PPM 600 500 400 300 200 100 0

SHIFT: 50Hz | 100Hz | 200Hz

SWEEP TIME

☑ 300/150 SEC ☐ / SEC

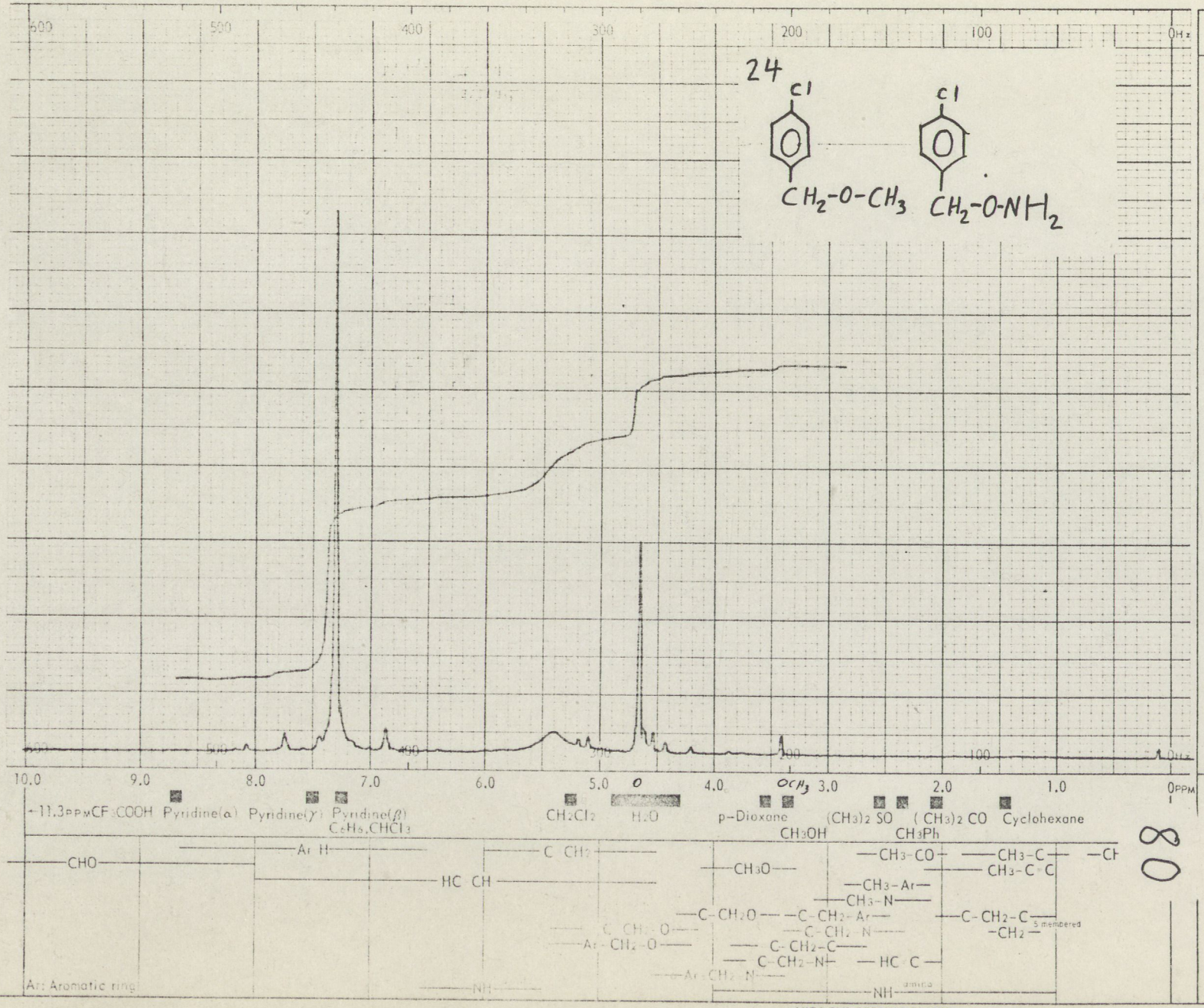
DATE: 2/4/75

OPERATOR R. Sommer

REMARKS:

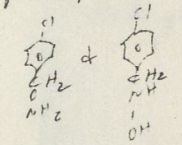
3.3 OMe
3.82 CH_2-N
4.35 CH_2-OCH_3
4.45 start
4.54 CH_2-O
5.92 exchgble
7.24 phenyl

74



1H SPECTRUM NO.: 29

SAMPLE: prod of 2/4/75



REFFERENCE: TMS

SOLVENT: $CDCl_3$

CONC: ? Sat.

AMPLITUDE:

SPECTRUM 5

INTEGRAL 5

H1 LEVEL: HI | NOR | LO

H2 LEVEL:

GAIN: ×1 | X10

SWEEP WIDTH: NOR / SCALE EXP.

10PPM 600 500 400 300 200 100 0

SHIFT: 50Hz | 600Hz | 600Hz

SWEEP TIME

☑ 300/150 SEC ☐ / SEC

DATE: 2/5/75

OPERATOR R. Sommer

REMARKS:

~~-NO2~~

O :W sol.

~~W sol~~

W sol is essentially zero

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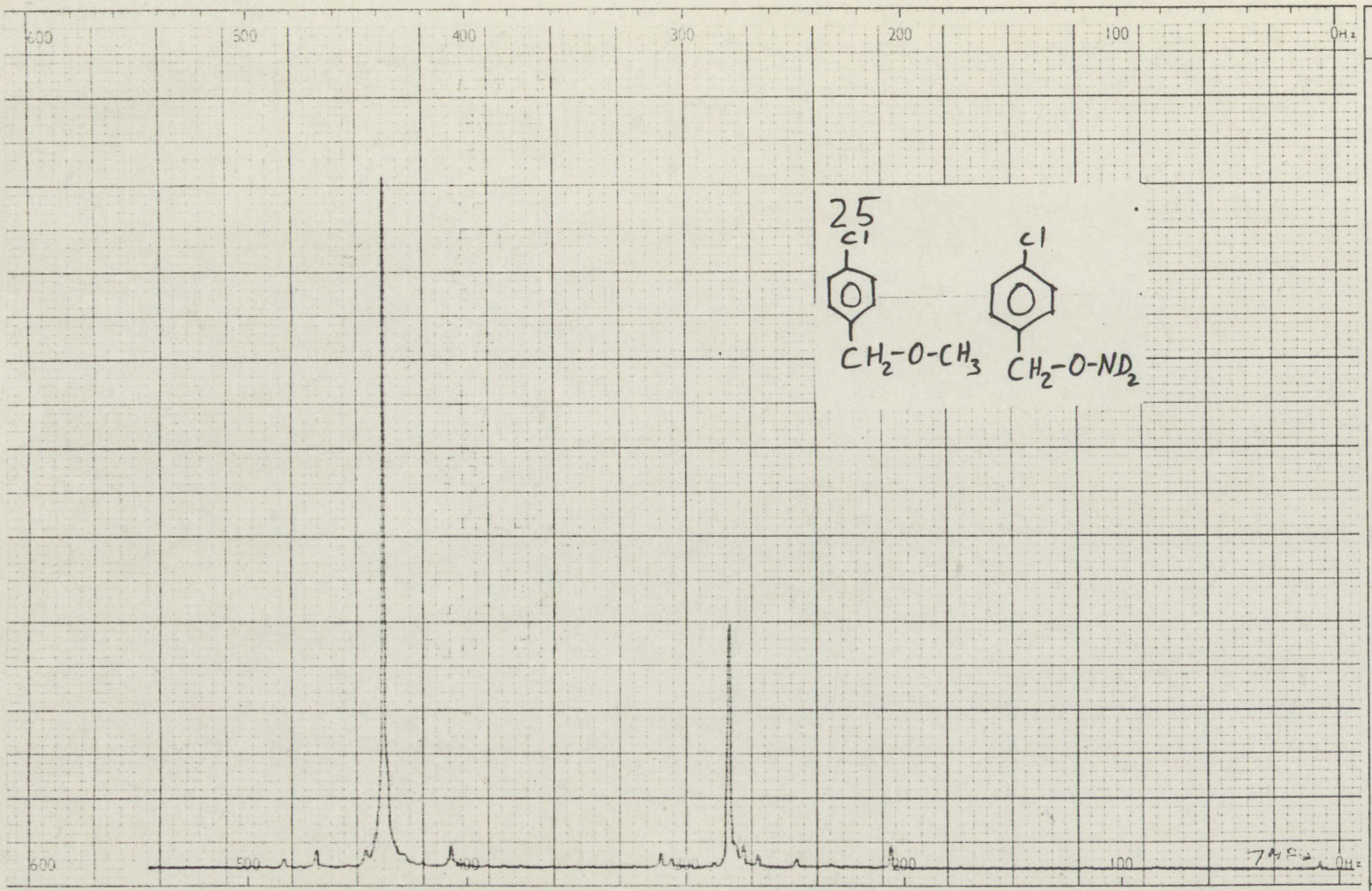
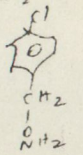


1H SPECTRUM NO.: 30

SAMPLE: prod of 2/4/75
D_2O exchgd



REFFERENCE: TMS
SOLVENT: $CDCl_3$, D_2O
CONC: sat
AMPLITUDE:
SPECTRUM 5
INTEGRAL
H1 LEVEL:
HI | NOR | LO
H2 LEVEL:
GAIN:
X1 | X10
SWEEP WIDTH:
NOR / SCALE EXP.
10PPM 600 500 400 300 200 100 0
SHIFT
50Hz | 600Hz | 600Hz
SWEEP TIME
☑ 300/150 SEC ☐ / SEC
DATE: 2/5/75
OPERATOR Sommer

REMARKS:
N:0 sat
1:16.

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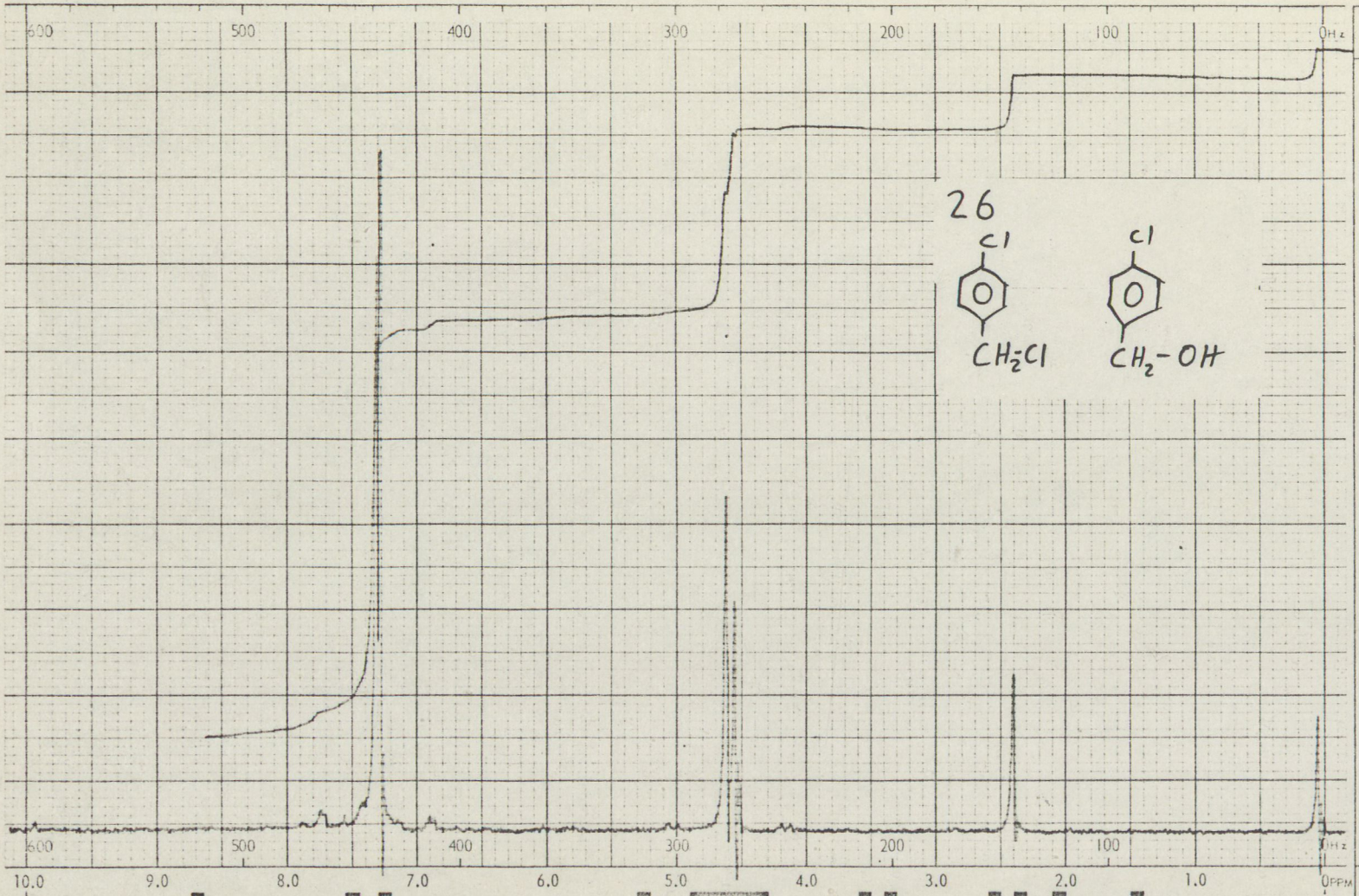
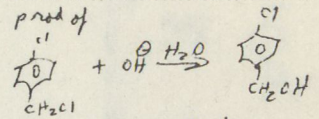


28

¹H SPECTRUM NO.:

SAMPLE: prod of



contains product + starting material

REFFERENCE: TMS

SOLVENT: $CDCl_3$

CONC: 5-10%

AMPLITUDE:

SPECTRUM 9

INTEGRAL

H1 LEVEL: H1 | N.R. | L.O.

H2 LEVEL:

GAIN: ✓ | x10

SWEEP WIDTH: NOR ✓ SCALE EXP.

10PPM 600 500 400 300 200 100 0

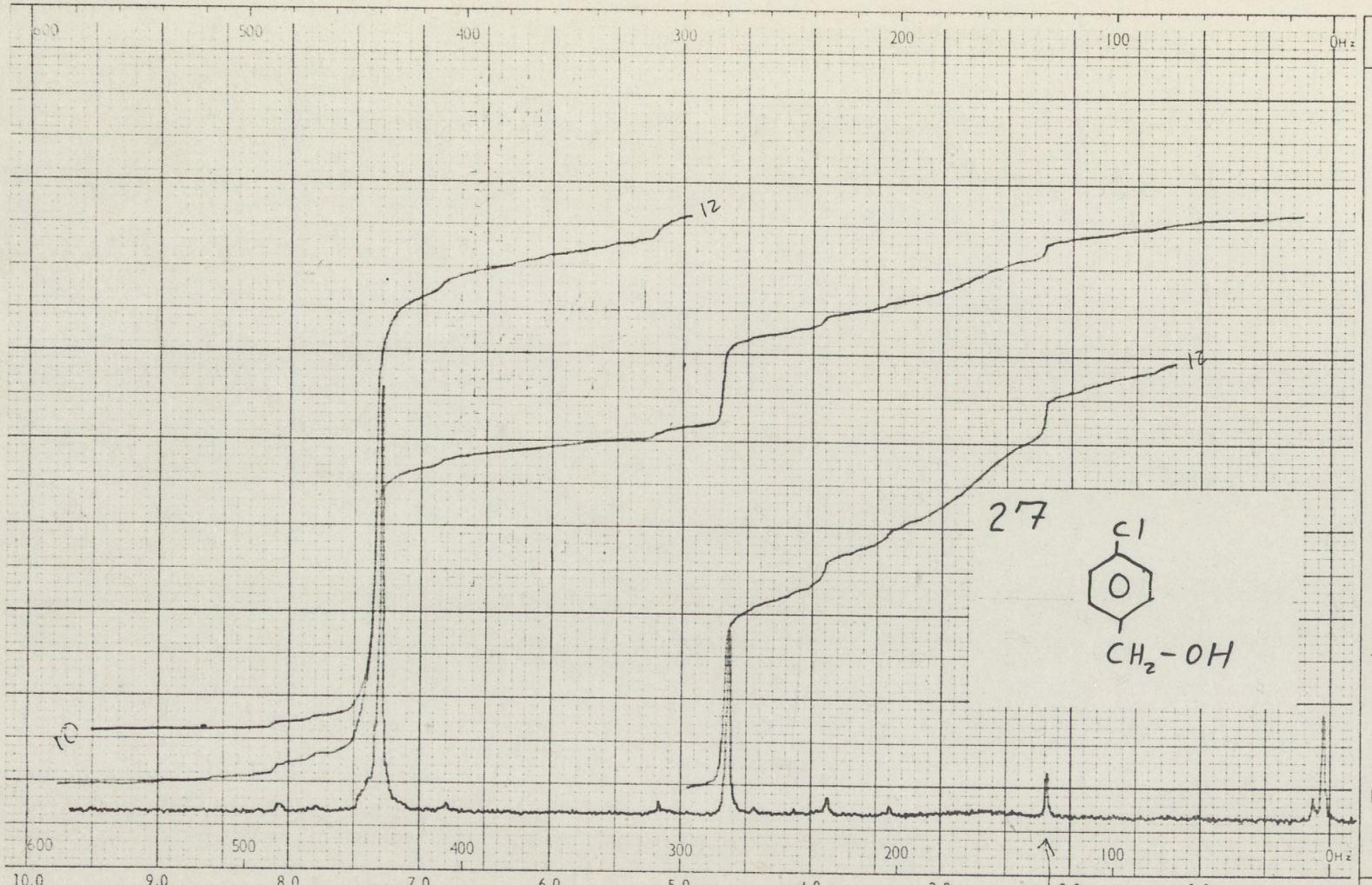
SHIFT 50Hz | 100Hz | 600Hz

SWEEP TIME ☑ 300/150 SEC ☐ / SEC

DATE: 2/13/75

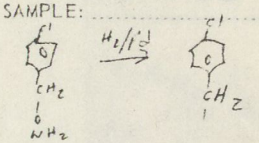
OPERATOR R. Sommer

REMARKS: Tube was rinsed $CHCl_3$.



1H SPECTRUM NO.: 31

SAMPLE:



2/6/75

REFFERENCE: TMS

SOLVENT: $CDCl_3$

CONC: 15-18%

AMPLITUDE:

SPECTRUM 9

INTEGRAL 12

H1 LEVEL:

HI | NOR | LO

H2 LEVEL:

GAIN:

X1 | X10

SWEEP WIDTH:

NOR | SCALE EXP.

10PPM 600 500 400 300 200 100 0

SHIFT

50Hz | 600Hz | 600Hz

SWEEP TIME

☑ 300/150 SEC ☐ / SEC

DATE: 2/7/75

OPERATOR R Donner

REMARKS: 2.3→3.3 PPM may be OH proton?

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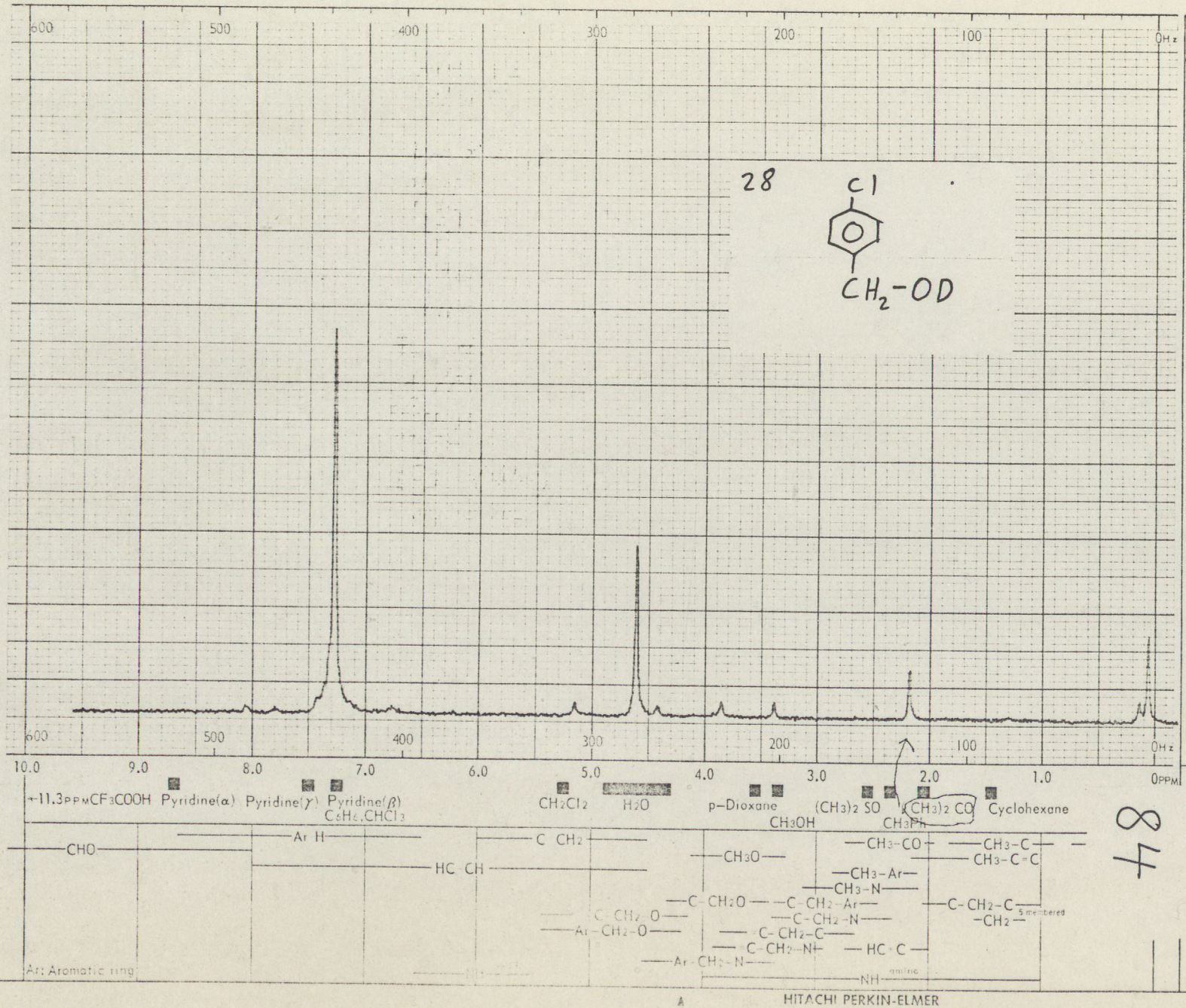
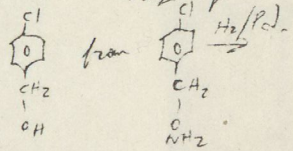


1H SPECTRUM NO.: 32

SAMPLE: D_2O X chloro cpd from  H_2/Pd.

REFFERENCE: TMS

SOLVENT: $CDCl_3$

CONC: ? 5-10%

AMPLITUDE:

SPECTRUM 9

INTEGRAL

H1 LEVEL: HI | NOR | LO

H2 LEVEL:

GAIN: X1 | X10

SWEEP WIDTH: NOR / SCALE EXP.

10PPM 600 500 400 300 200 100 0

SHIFT: 50Hz | 600Hz | 600Hz

SWEEP TIME: ☑ 300/150 SEC ☐ / SEC

DATE: 2/7/75

OPERATOR R. Downes

REMARKS:

Note: no bridge from 2.3 - 3.3 ppm. Elimination of the OH peak.

8 of 8

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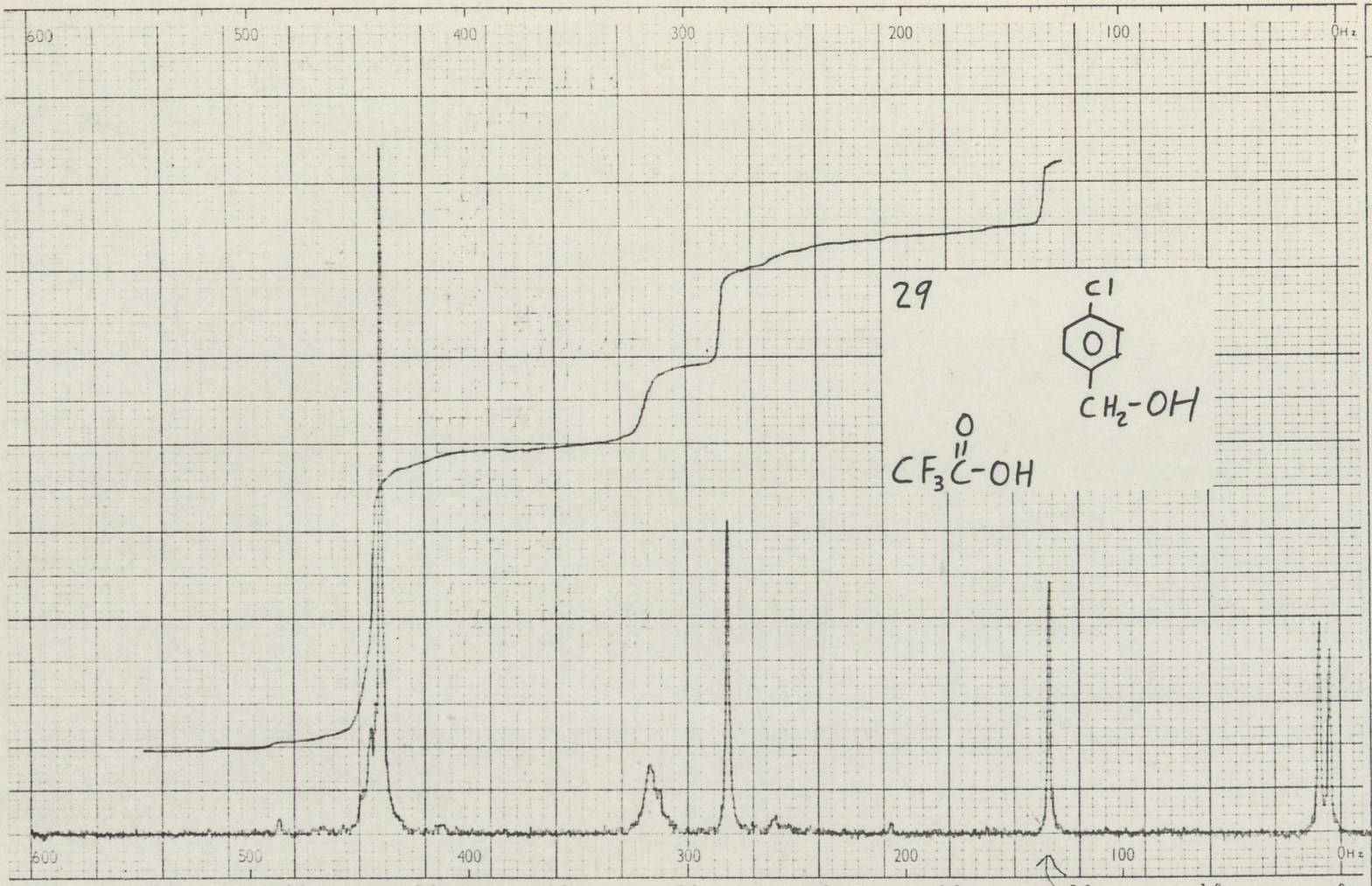
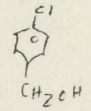


1H SPECTRUM NO.:

SAMPLE:



= CF_3COOH added

REFFERENCE: TMS

SOLVENT: $CDCl_3$

CONC: ?

AMPLITUDE:

SPECTRUM 11

INTEGRAL

H1 LEVEL: HI | NOR | LO

H2 LEVEL:

GAIN: X1 | X10

SWEEP WIDTH: NOR / SCALE EXP.

10PPM 600 500 400 300 200 100 0

SHIFT 50Hz | 600Hz | 600Hz

SWEEP TIME

☑ 300/150 SEC ☐ / SEC

DATE: 2/10/75

OPERATOR R. Sommer

REMARKS:

85

Ar: Aromatic ring

HITACHI PERKIN-ELMER

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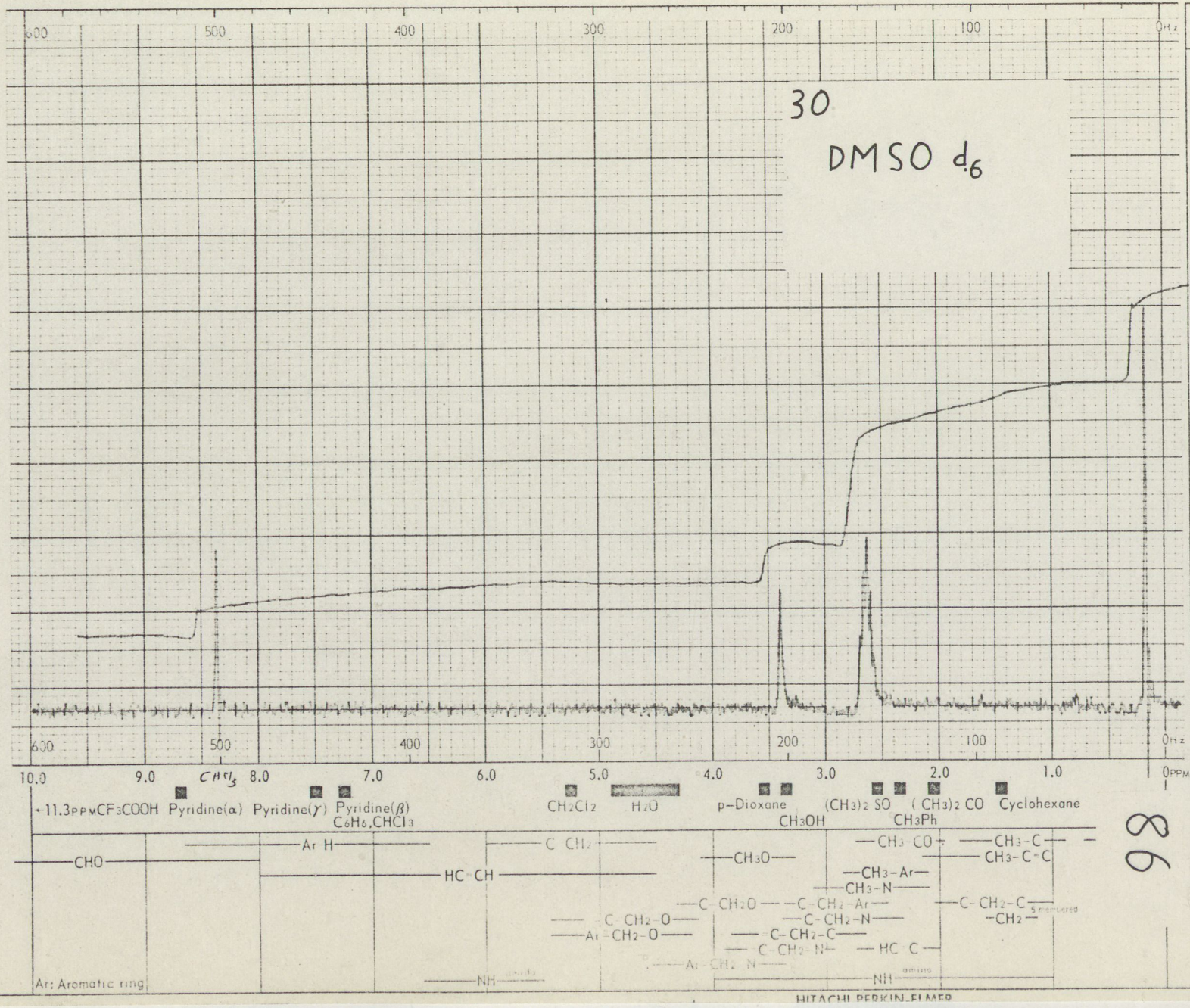
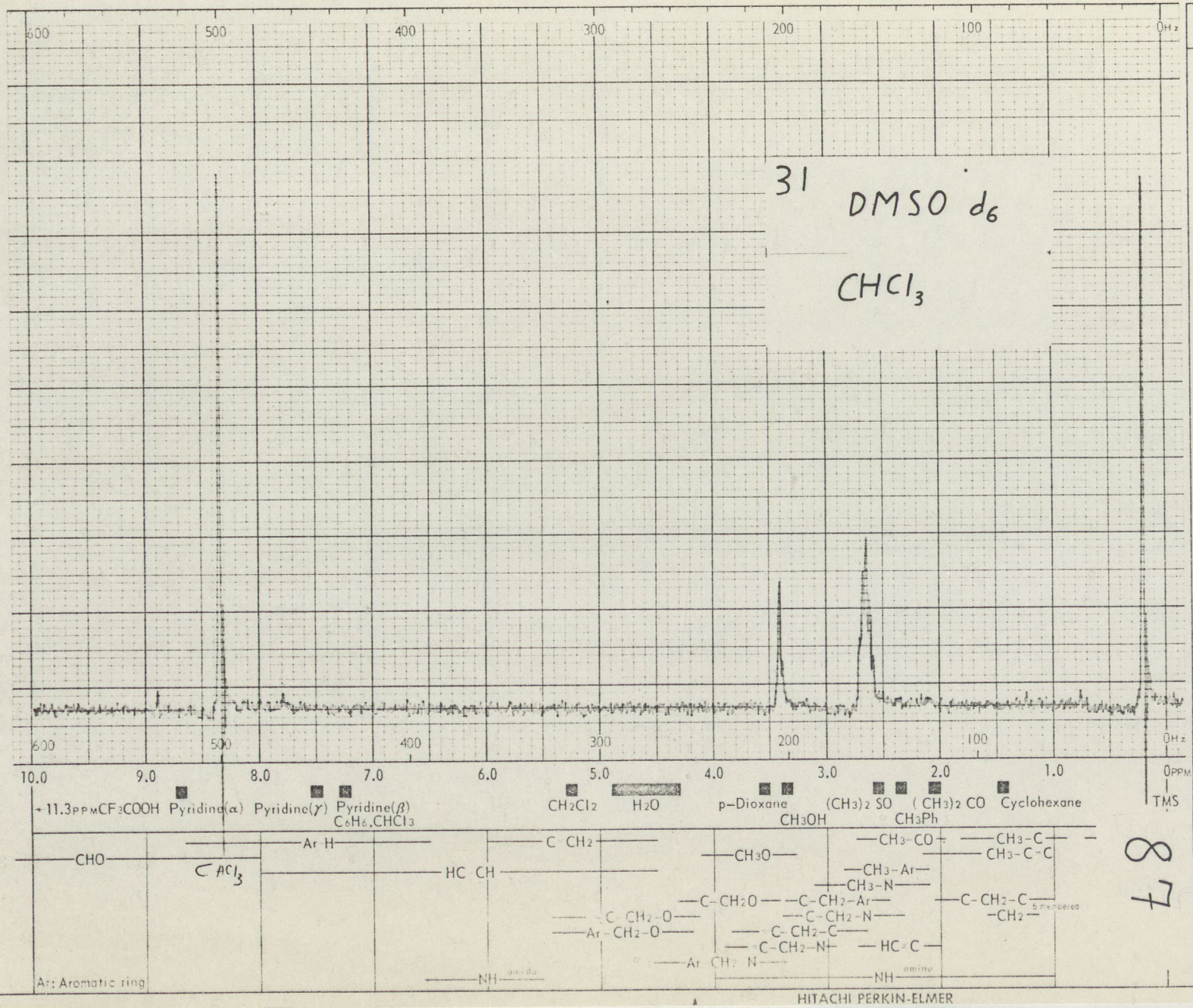

30
DMSO d6
600
500
400
300
200
100
0Hz
10.0
9.0
CHCl3
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0PPM
~11.3PPM CF3COOH
Pyridine(α)
Pyridine(γ)
Pyridine(β)
C6H6, CHCl3
CH2Cl2
H2O
p-Dioxane
CH3OH
(CH3)2SO
CH3Ph
(CH3)2CO
Cyclohexane
CHO
Ar H
HC=CH
C-CH2-
CH3O-
CH3-CO-
CH3-C-
CH3-C=C
CH3-Ar
CH3-N
C-CH2O
C-CH2-Ar
C-CH2-C
5 membered
C-CH2-O
C-CH2-N
CH2
Ar-CH2-O
C-CH2-C
C-CH2-N
HC-C
Ar-CH2-N
NH amide
NH amine
Ar: Aromatic ring
HITACHI PERKIN-ELMER
CHART NO. 435-7204
PRINTED IN U.S.A.
MADE IN U.S.A.
1H SPECTRUM NO.:
SAMPLE: DMSO d6
REFFERENCE: TMS
SOLVENT: none
CONC: neat
AMPLITUDE:
SPECTRUM 12
INTEGRAL 12
H1 LEVEL:
HI NOR LO
H2 LEVEL:
GAIN:
X X10
SWEEP WIDTH:
NOR SCALE EXP.
10PPM 600 500 400 300 200 100 0
SHIFT
50Hz 600Hz 600Hz
SWEEP TIME
300/150 SEC / SEC
DATE: 3/4/75
OPERATOR R. Sommer
REMARKS:
CHCl3 was used to run the table



1H SPECTRUM NO.:

SAMPLE: $CHCl_3$ in DMSO d_6

REFFERENCE: TMS

SOLVENT: DMSO

CONC: ?

AMPLITUDE:

SPECTRUM 12

INTEGRAL

H1 LEVEL: ✓ (HI | NOR | LO)

H2 LEVEL:

GAIN: ✓ (X | X10)

SWEEP WIDTH:

NOR ✓ SCALE EXP.

10PPM 600 500 400 300 200 100 0

SHIFT (50Hz | 600Hz | 600Hz)

SWEEP TIME

☑ 300/150 SEC ☐ / SEC

DATE: 3/4/75

OPERATOR R. Deanna

REMARKS:

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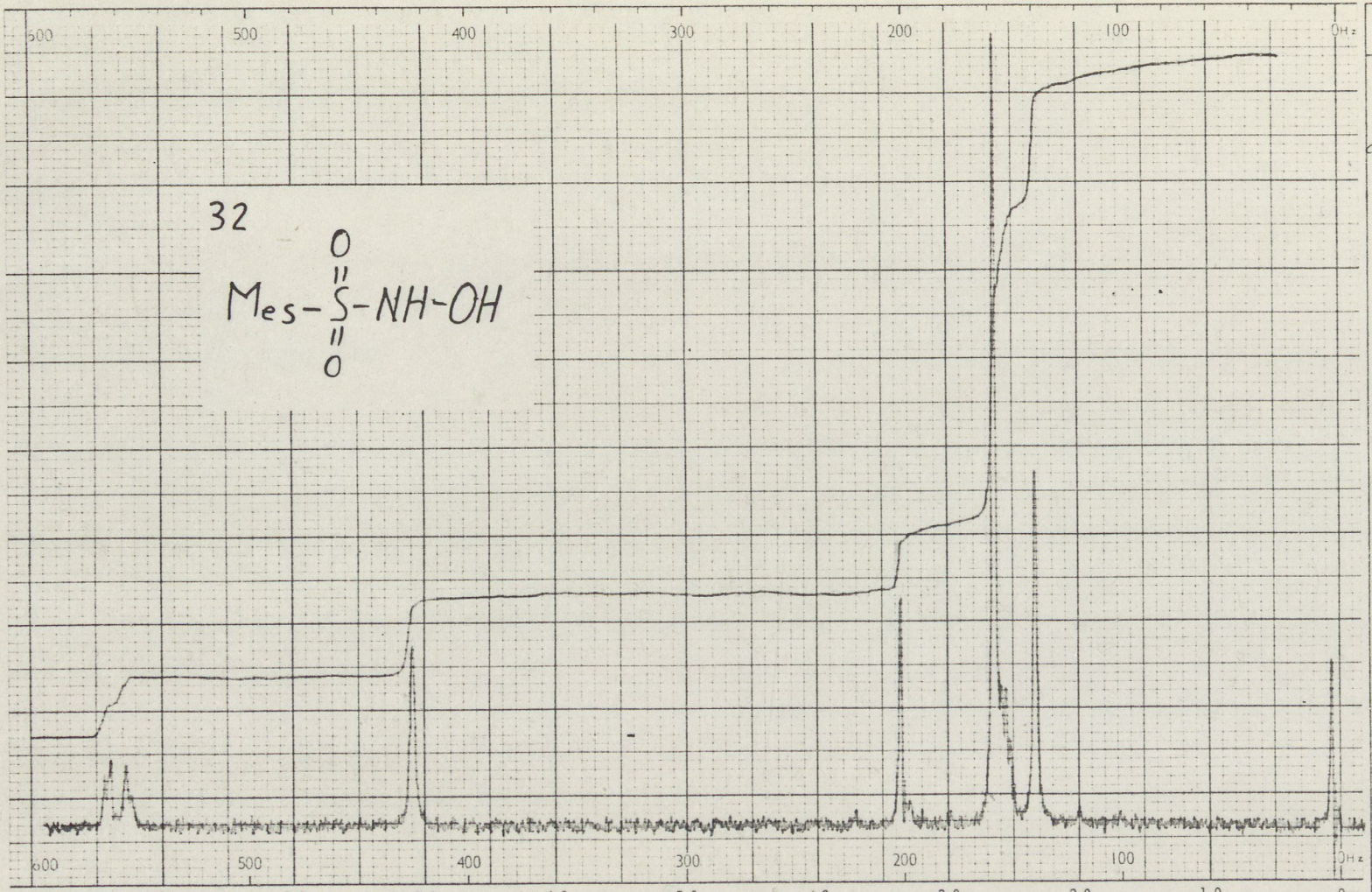
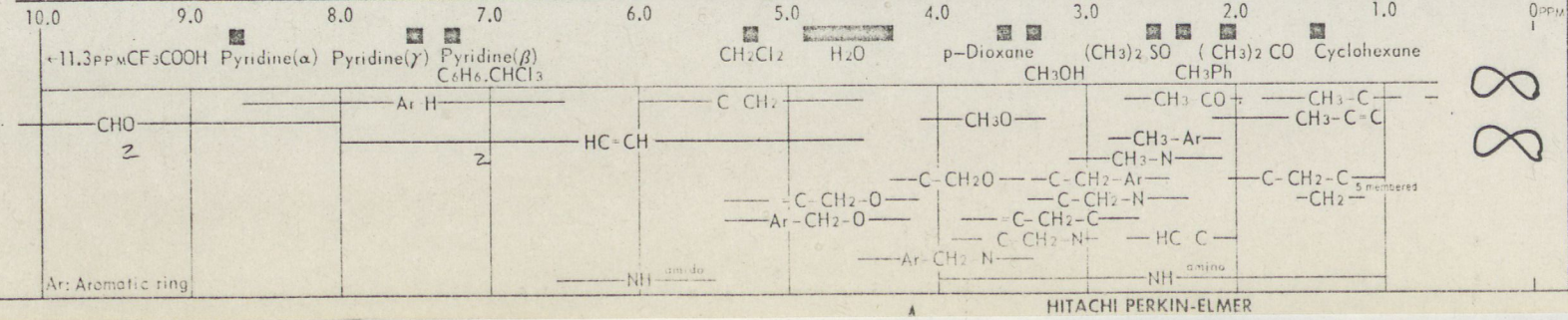
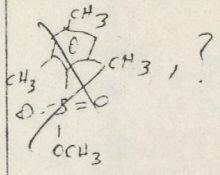
Mes-S(=O)(=O)-NH-OH





1H SPECTRUM NO.:

SAMPLE:



REFFERENCE: TMS
SOLVENT: DMSO
CONC: low

AMPLITUDE:
SPECTRUM 12
INTEGRAL 12

H1 LEVEL:

H1 | NOR | LO

H2 LEVEL:

GAIN:

✓ | X10

SWEEP WIDTH:

NOR ✓ SCALE EXP.

10PPM 600 500 400 300 200 100 0

SHIFT

50Hz | 600Hz | 650Hz

SWEEP TIME

☑ 300/150 SEC ☐ / SEC

DATE 3/3/75

OPERATOR R. Sommer

REMARKS:

2.25
2.57
3.30 H2O
7.65 (2)
9.2
9.35

HITACHI PERKIN-ELMER

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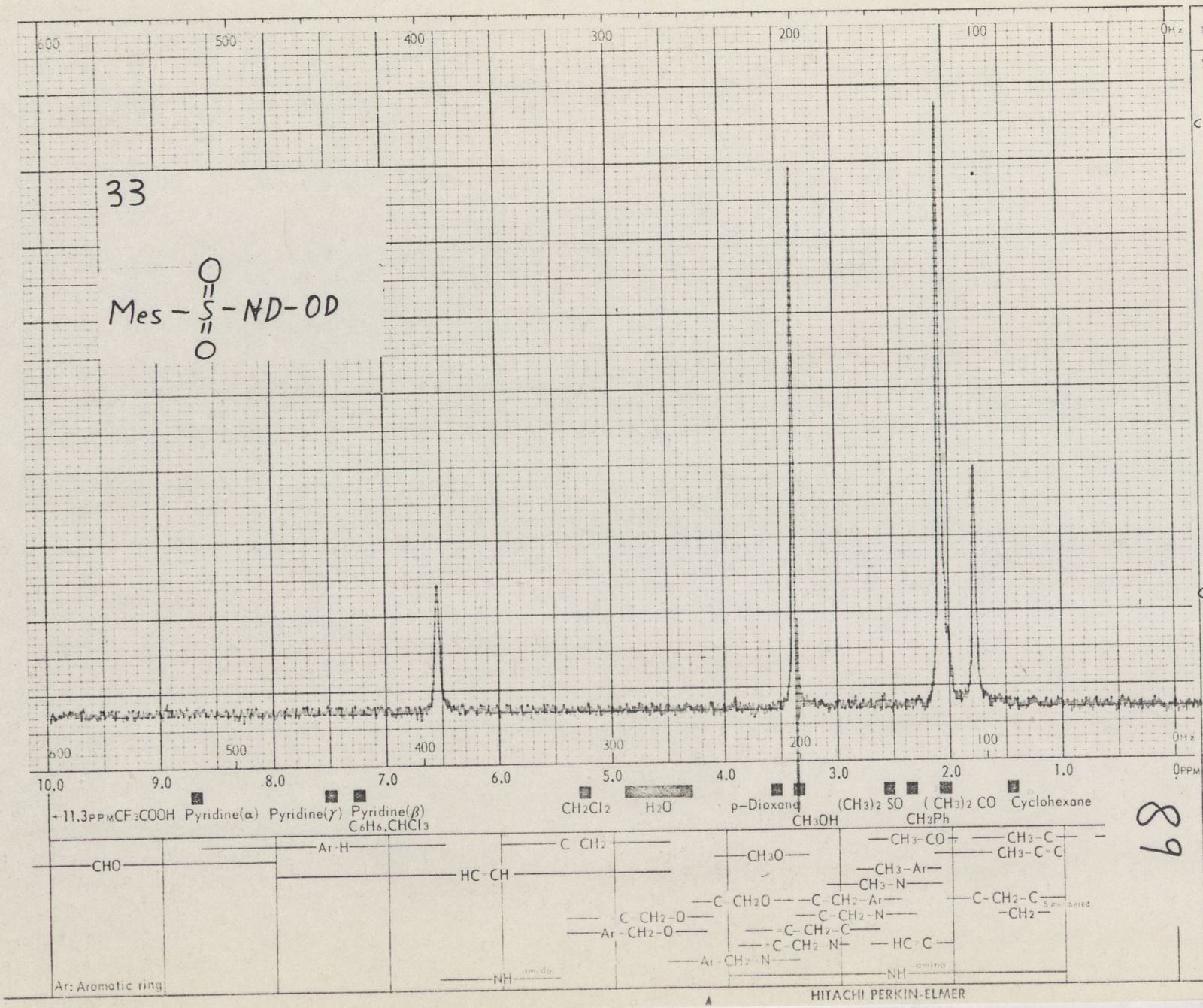
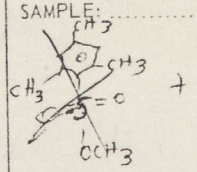


1H SPECTRUM NO.:

SAMPLE:



+ ?

∈ D_2O x-close

REFFERENCE: TMS - ?

SOLVENT: ~~DO~~ DMS.

CONC: ?

AMPLITUDE:

SPECTRUM 12

INTEGRAL

H_1 LEVEL:

HI | NOR ✓ | LO

H_2 LEVEL:

GAIN:

✓ | X10

SWEEP WIDTH:

NOR ✓ SCALE EXP.

10PPM 600 500 400 300 200 100 0

SHIFT → 5 0ppm

50Hz | 600Hz | 600Hz

SWEEP TIME

☑ 300/150 SEC ☐ / SEC

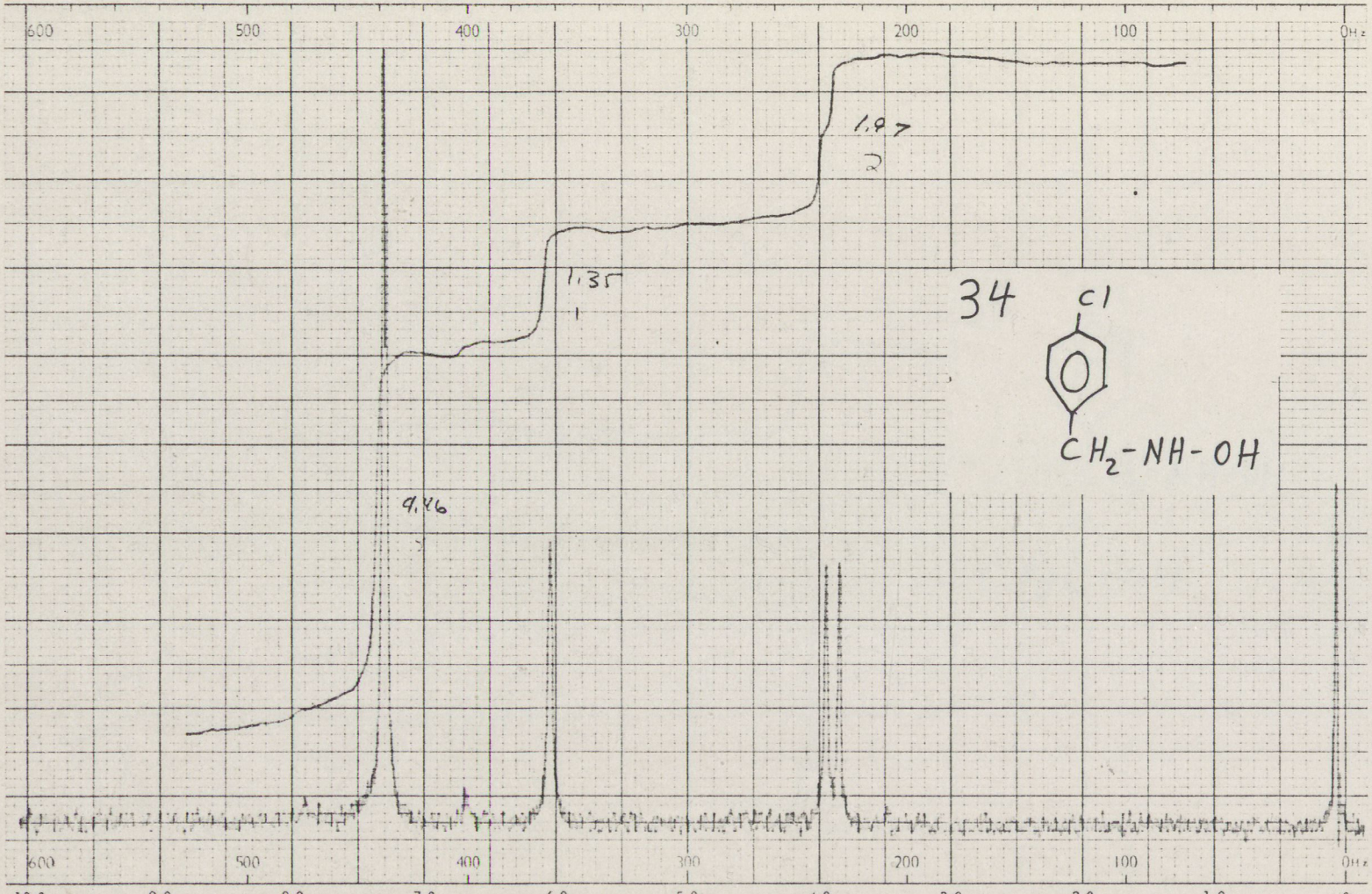
DATE: 3/3/75

OPERATOR R. Domm

REMARKS:

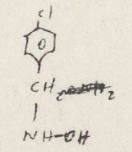
HITACHI PERKIN-ELMER

CHART NO. 435-7204 PRINTED IN U.S.A.



1H SPECTRUM NO.:

SAMPLE:



REFFERENCE: TMS

SOLVENT: $CDCl_3$

CONC: ~5-10%

AMPLITUDE:

SPECTRUM 13

INTEGRAL 13

H1 LEVEL:

HI | NOR | LO

H2 LEVEL:

GAIN:

X1 | X10

SWEEP WIDTH:

NOR SCALE EXP.

10PPM 600 500 400 300 200 100 0

SHIFT

50Hz | 600Hz | 600Hz

SWEEP TIME

☑ 300/150 SEC ☐ / SEC

DATE: 2/17/75

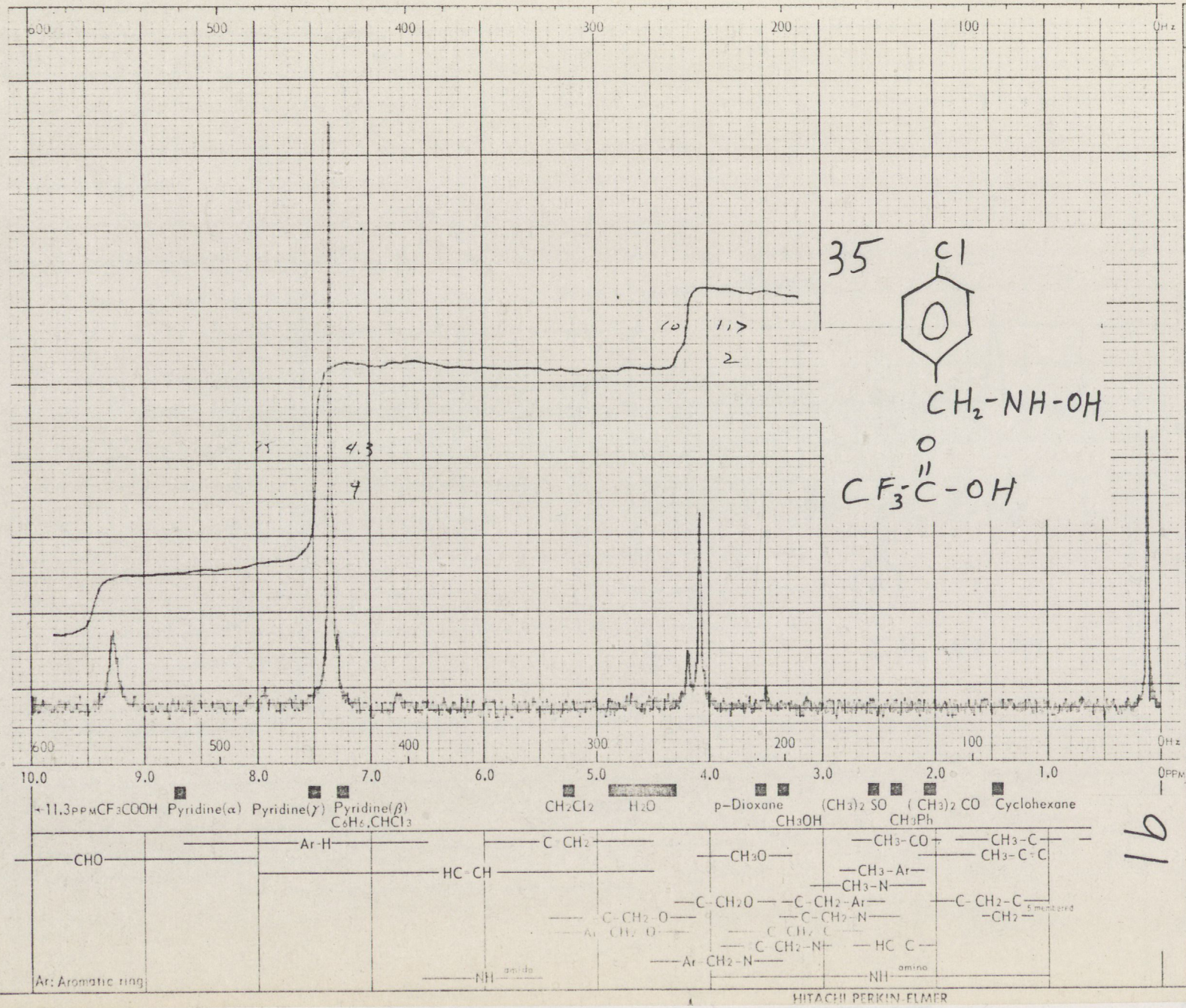
OPERATOR R. Donnan

REMARKS:

3.82 CH_2

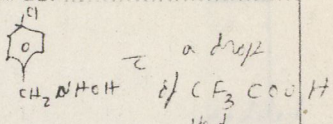
5.96 NH, OH

7.32



1H SPECTRUM NO.:

SAMPLE:



REFFERENCE: TMS

SOLVENT: $CDCl_3$

CONC: ~5%

AMPLITUDE:

SPECTRUM 13

INTEGRAL 13

H1 LEVEL:

HI | NOR ✓ | LO

H2 LEVEL:

GAIN:

X1 ✓ | X10

SWEEP WIDTH:

NOR ✓ SCALE EXP.

10PPM 600 500 400 300 200 100 0

SHIFT

50Hz 600Hz 600Hz

SWEEP TIME

☑ 300/150 SEC ☐ / SEC

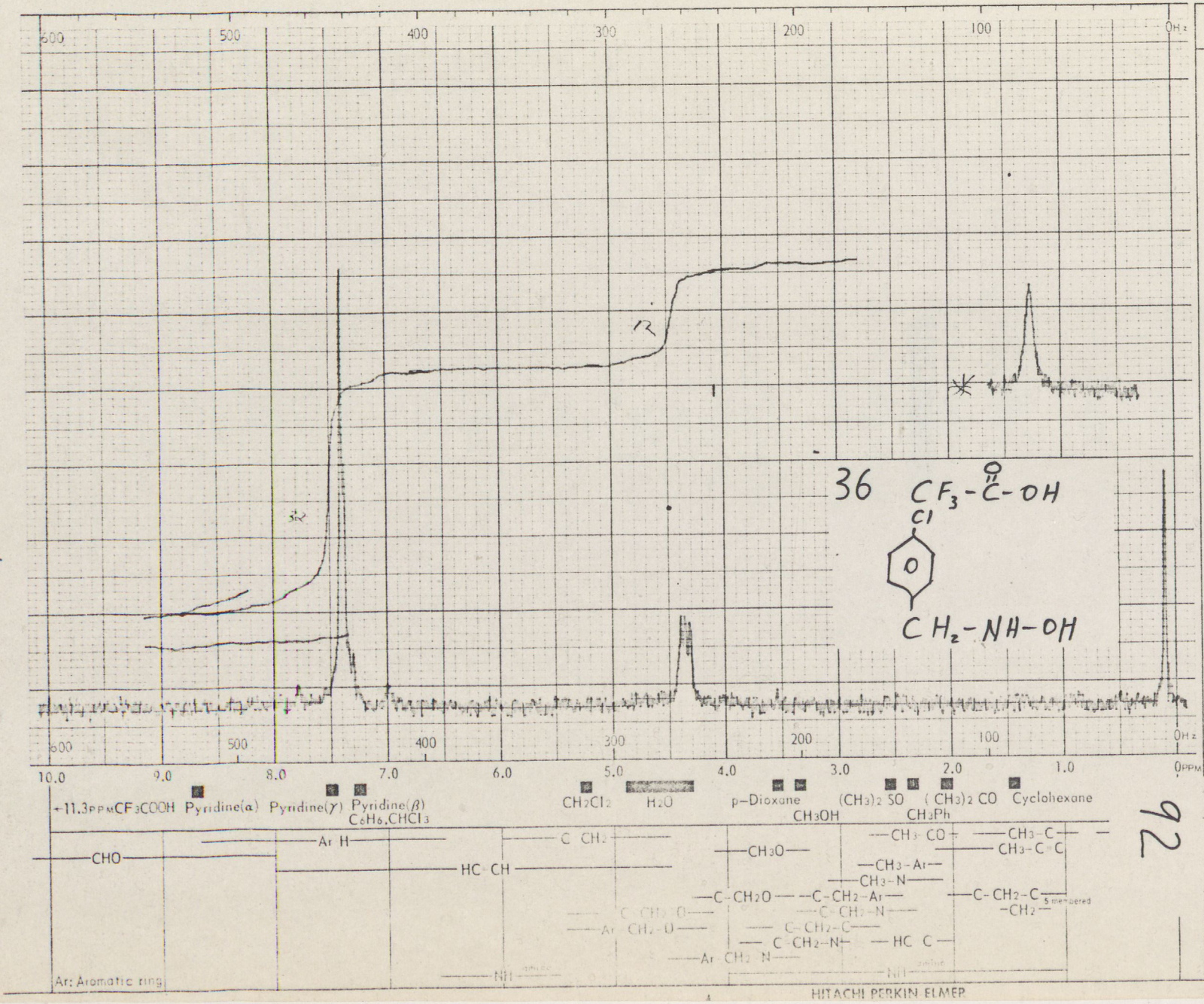
DATE: 2/17/75

OPERATOR K. Simmons

REMARKS:

HITACHI PERKIN-ELMER

CHART NO. 425-7004

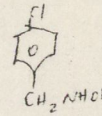


36 $CF_3-\overset{O}{\overset{\|}{C}}-OH$

$CH_2-NH-OH$

1H SPECTRUM NO.:

SAMPLE:



ε rose CF_3COOH added.

REFFERENCE: TMS
SOLVENT: $CDCl_3$
CONC: ~5-10%

AMPLITUDE:
SPECTRUM 13
INTEGRAL 13

H1 LEVEL: HI | NOR ✓ | LO

H2 LEVEL:

GAIN: X ✓ | X10

SWEEP WIDTH: NOR / SCALE EXP.
10PPM 600 500 400 300 200 100 0

SHIFT 50Hz | 600Hz | 800Hz

SWEEP TIME
☑ 300/150 SEC ☐ / SEC

DATE: 2/17/75

OPERATOR R. Detrmer

REMARKS:

* 600 →

The triplet at 4.35 δ is due to N^{14} coupling to the CH_2 group. See notebook page 119 for the reference

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HITACHI PERKIN ELMER

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