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The Hofmann degradation of Oxamide and Urea

Carmen Michael Cusano
Union College - Schenectady, NY

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THE HOFMANN DEGRADATION
OF
OXAMIDE AND UREA

THE HOFMANN DEGRADATION

OF

OXAMIDE AND UREA

A thesis presented to the Department of
Chemistry of Union College in partial fulfill-
ment of the requirements for the degree of
Bachelor of Science with a major in Chemistry.

Submitted by

Michael
Carmen M. Cusano

Approved by

Howard E. Stuffer

May 27, 1955

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INTRODUCTION

An amide may be degraded to an amine using the Hofmann reaction. The theoretical product of the Hofmann reaction of oxamide is hydrazine.

The objective of this project was the production of hydrazine from oxamide. Since hydrazine could not be obtained from oxamide, an extensive study was made of the production of hydrazine from urea.

It was hoped that the background gained in the study of the urea reaction could be applied to the original problem, i.e. the formation of hydrazine from oxamide. However, even with this background, no hydrazine was obtained from oxamide.

HISTORICAL

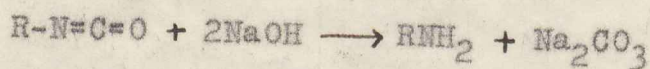
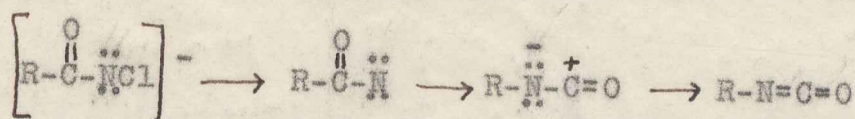
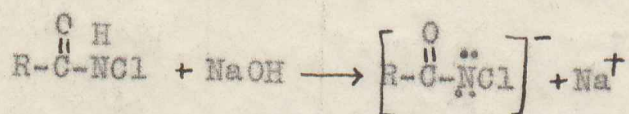
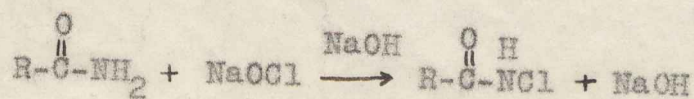
Several students at Union College have investigated the Hofmann reaction of diamides. Those studied were sebacamide, adipamide, and succinamide. The author has centered his attention upon oxamide and urea.

In looking over work done at Union, it is seen that sebacamide did not yield octamethylene diamine,⁽¹⁾ perhaps due to the great insolubility of this amide. Adipamide resulted in the formation of tetramethylene diamine⁽²⁾ (putrescine). Succinamide yielded both the expected ethylene diamine and dihydrouracil.⁽³⁾ In the case of adipamide, it was reported that better yields of product could be obtained using sodium hypochlorite than sodium hypobromite. For this reason and because of its ready availability in the form of "chlorox", sodium hypochlorite was used in this work.

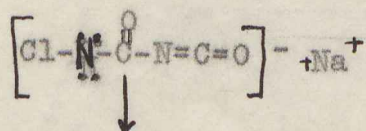
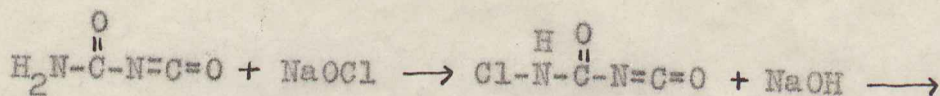
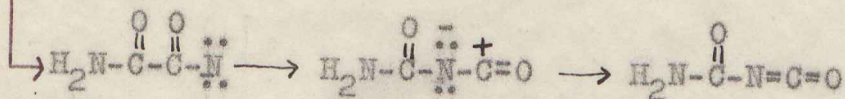
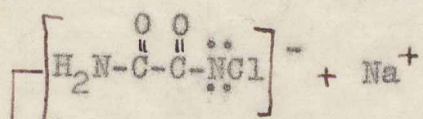
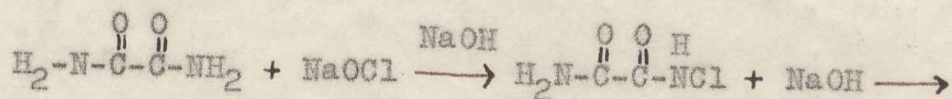
It was first thought that the standard procedure could be employed directly in obtaining hydrazine from oxamide. With this in mind, the first experiments were carried out using the same methods as those used by other students at Union.

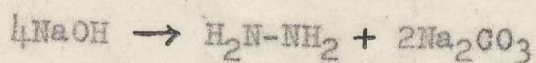
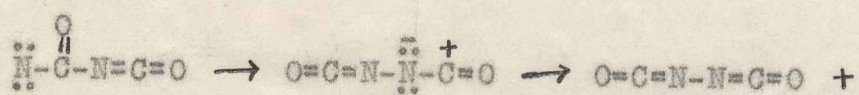
In the Hofmann reaction an amide reacts with the sodium hypochlorite and sodium hydroxide. A rearrangement occurs giving an isocyanate which in turn is converted to an amine. The net effect is that an amide is transformed to an amine with one less carbon atom.

The general reaction mechanism shown below is Whitmore's mechanism. (8)

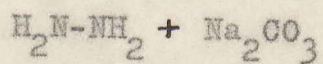
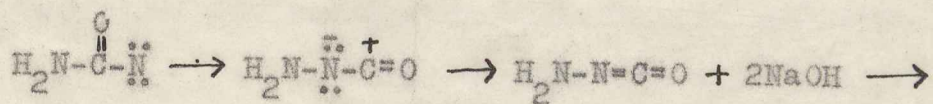
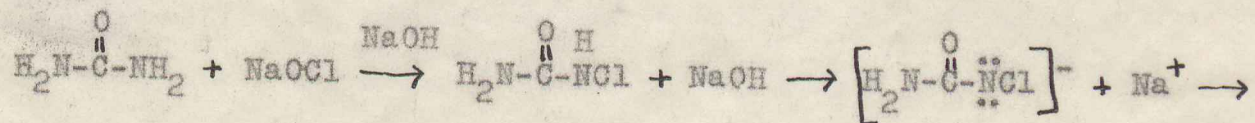


Applying this reaction mechanism to oxamide we have the following:





The Hofmann reaction with urea can be shown as follows:



EXPERIMENTAL

I. Hofmann degradation of amides according to the standard procedure.

A. Adipamide

The Hofmann reaction was run with adipamide to gain experience for running the reaction with oxamide. This technique was applied to both oxamide and urea.

Chlorox was found to have a density of 1.08g/cc. and a chlorine content of 5%.

Run 11

Reagents	Adipamide	NaOCl	NaOH		H ₂ O	
Mole Ratio	1	2	(1) 4.5	(2) 3.5	(1) 165	(2) 30
Moles	0.032	0.064	0.144	0.112	5.3	0.96
Weight	4.70gm.	4.77gm.	5.76gm.	4.48gm.	95.5gm.	17.3gm.

Run 11

The apparatus used in this reaction consisted of a three neck flask fitted with a thermometer and still head unit, a mechanical stirrer, and a separatory funnel. The still head was connected to a trap which in turn was connected to a flask containing a known volume of standard hydrochloric acid.

The adipamide was added to the water (1) with stirring. The sodium hydroxide and chlorox solution was then added by means of the separatory funnel. The temperature of the flask

was maintained below 5°C . for forty minutes. At the end of this time the remaining sodium hydroxide and water (2) were added and the solution was heated to $80-85^{\circ}\text{C}$. for approximately ten minutes. Before heating, the solution was odorless and faintly green but after it was heated it became yellowish having a penetrating odor characteristic of putrescine.

The product was isolated as the N,N dibenzoyl derivative of putrescine using benzoyl chloride to precipitate the putrescine. The crude product yield was equal to 82.1%. This product was recrystallized from alcohol and water where the yield of pure derivative was 67.4%. This derivative was a white powder melting at $176-178^{\circ}\text{C}$. The melting point of the N,N dibenzoyl derivative of putrescine in Heilbron: Dictionary of Organic Compounds was given as 177°C .

At the conclusion of this reaction, titration of the acid in the ammonia trap revealed that no ammonia had been liberated during the reaction.

B. Oxamide

Runs 12,13

Reagents	Oxamide	NaOCl	NaOH	H ₂ O
			(1) (2)	(1) (2)
Mole Ratio	1	2	4.5 3.5	165 30

Oxamide was studied in the same apparatus mentioned above. In reaction 12, the times and temperatures were exactly the same as those of run 11. However, in run 13, the reaction time at

80°C. was increased to one hour. The ammonia trap was omitted in runs 12-16.

Samples from both these reactions were analyzed for hydrazine (see pages 16-18). Neither reaction produced hydrazine. The insolubility of oxamide may have been responsible for these negative results. The Handbook of Chemistry and Physics gives the solubility of oxamide as 0.04g./100g. of water at 7°C.

Run 14

Reagents	Oxamide	NaOCl	NaOH		H ₂ O	
			(1)	(2)	(1)	(2)
Mole Ratio	1	2	4.5	3.5	1550	30

In reaction 14 with oxamide, the mole ratio of water was increased by a factor of approximately nine. Otherwise, the reaction was run just as the preceding one, i.e. the reaction time at 80°C. was one hour. Analysis of a sample from this batch showed that no hydrazine was produced.

C. Urea

Run 15

Reagents	Urea	NaOCl	NaOH		H ₂ O	
			(1)	(2)	(1)	(2)
Mole Ratio	1	2	4.5	3.5	1550	30

Run 16

Reagents	Urea	NaOCl	NaOH		H ₂ O	
			(1)	(2)	(1)	(2)
Mole Ratio	1	1	4.5	3.5	1550	30

Attempts to prepare hydrazine from urea using the method similar to reaction 14 were unsuccessful. In run 15, the mole

ratio of sodium hypochlorite to urea was two to one, whereas in run 16, this ratio was one to one.

II. Hofmann degradation of amides according to German patent No. 1 (6).

A. Urea

Following this, two German patents were secured which demonstrated the production of hydrazine from urea. These methods were given careful consideration and both were exploited in an effort to produce hydrazine. The first method is described below.

Runs 21, 22

Reagents	Urea	NaOCl	NaOH	H ₂ O
Mole Ratio	1	0.001	2.2	20.2
Moles	0.256	0.000256	0.558	5.55
Weight	15.4gm.	0.0191gm.	22.3gm.	100gm.

The apparatus for this method consisted of the following. Two separatory funnels were connected to an addition tube (y tube) which in turn was connected to a pyrex glass reaction tube encased in a furnace. This tube was adapted especially to contain a thermometer which measured the temperature of the passing liquid.

The urea was added to the previously prepared sodium hydroxide solution already cooled to about 15°C. The alkali-urea solution was poured into one separatory funnel and the chlorox solution was poured into the other separatory funnel. The two were

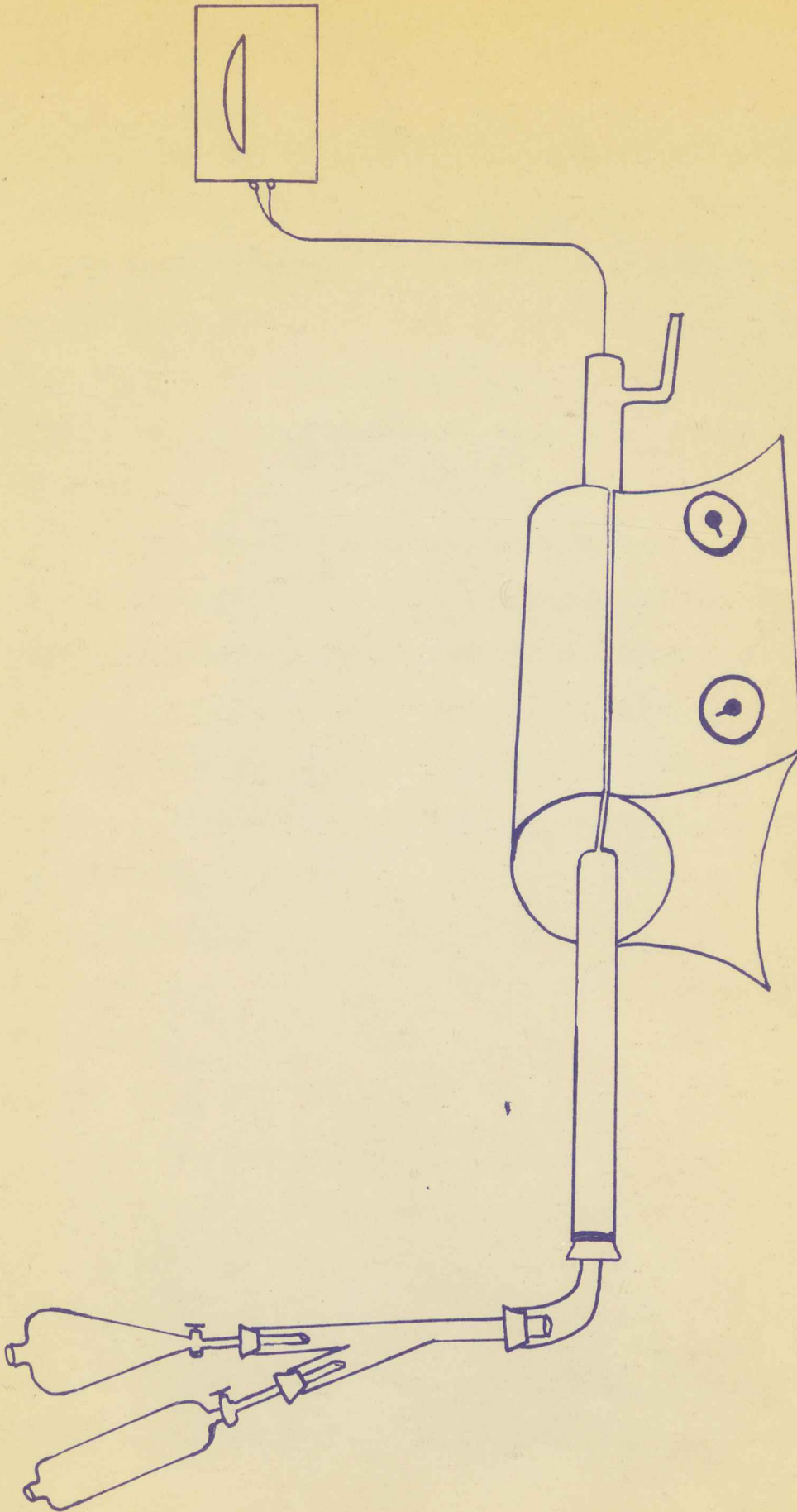


Fig. 1 - Apparatus Used in Runs 22-26

adjusted to flow at a slow rate into the previously heated reaction tube. In this way, the reactants went from approximately room temperature to 100°C. in a short time. This entire reaction required about twenty minutes.

No results were obtained from run 21 because the pyrex glass reaction tube shattered under the severe temperature strains.

In run 22, a steel reaction tube was used.* The steel reaction tube contained a thermocouple at the outlet end. This permitted the temperature of the liquid to be recorded. The temperature was the temperature near the exit of the tube.

Analysis of the product indicated that no hydrazine was formed. The reason for this was the small mole ratio of sodium hypochlorite to urea.

Runs 23,24,25,26

Reagents	Urea	NaOCl	NaOH	H ₂ O
Mole Ratio	1	1	2.2	20.2

Run 23

The patent was suspected of being in error concerning the mole ratio of urea to sodium hypochlorite. For run 23, the ratio of urea to sodium hypochlorite was charged to one to one. This reaction was run exactly as described above, i.e. twenty minutes were required to complete the reaction. Analysis showed that no hydrazine had been formed.

*See Figure 1.

Run 24

Run 24 was similar to run 23 except for the fact that the total reaction time was increased from twenty minutes to one hour. This was accomplished by adjusting the rate of flow of reagents from the separatory funnels. However, analysis of the product established that hydrazine was not present.

Run 25

In this run, the reaction time at 100°C. was increased by collecting the product in a three neck flask that could be heated. This flask was fitted with an inlet tube and a water-jacketed condenser. The product remained at 100°C. for about fifteen minutes before allowing it to cool. No hydrazine was formed by this reaction.

Run 26

This reaction was run slightly different from the preceding ones. It was thought that perhaps a longer contact time before heat was applied to the system might help because the reaction rate for the formation of the N chloramide of urea might be slow.

To facilitate this longer contact time, the alkali-urea solution was mixed with the chlorox solution. One separatory funnel admitted this mixture with the reaction tube. This step increased the contact time before heating from approximately ten seconds to ten minutes. This, of course, meant that the total reaction time at 100°C. was reduced by a factor of one-half

since the total reaction time was ten minutes as compared to a total reaction time of twenty minutes in run 22. Analysis showed that hydrazine was not produced under these conditions.

III. Hofmann degradation of amides according to German patent No. 2 (7).

A. Urea

At this point another method was employed in an effort to produce hydrazine from urea. This method was obtained from a second German patent (7). It is described below.

Run 31

Reagents	Urea	NaOCl	NaOH	H ₂ O	Catalyst
Mole Ratio	1	1	2.66	1.5	MnSO ₄
Moles	0.20	0.20	0.530	1.3	1*
Weight	12.0gm.	14.9gm.	21.2gm.	25gm.	

1* indicates that 3ml. of a 1/2% MnSO₄ solution was used here.

The apparatus for this reaction consisted of a three neck flask fitted with a mechanical stirrer, a water jacketed condenser and a thermometer.

The technique involved in all these reactions was much the same. The urea was added to the reaction flask dry. The alkali-hypochlorite solution including the catalyst (MnSO₄) was cooled to temperature of 10-15°C. This mixture was then added rapidly with stirring to the reaction flask containing the urea. Heat was then applied to the flask to produce boiling. This required about five minutes. Before the boiling occurred, the presence

of manganese dioxide was indicated by its characteristic brown precipitate. Much gas, probably carbon dioxide, ammonia was given off during this time due to the temperature change. The reaction was held at the boiling point for five minutes and then allowed to cool. This solution assumed the appearance of a sol, but it cleared on standing.

Run 31

Analysis of the product obtained in the manner described above showed that hydrazine was produced. A yield of 58.3% hydrazine was obtained based on urea (see pages 16-18). This patent specified that yields of 60% to 70% of the theoretical yield were obtainable.

In the succeeding runs, the optimum conditions for producing hydrazine from urea were determined. These results are shown in the table below.

<u>Run</u>	<u>Time at Temp. 10-15°C.</u>	<u>Time at Temp.=B.P.</u>	<u>Catalyst (Amt.)</u>	<u>Yield %</u>
32	0	5	1	68.4%
33	0	10	1	69.9%
34	10	5	1	47.0%
35	0	5	2*	43.7%
36	0	5	1/2*	48.1%

*2 indicates twice the amount used in run 31.

*1/2 indicates 1/2 the amount used in run 31.

Run 37

The method of #31 was applied to urea using 0.5 gm. of gelatin as a catalyst instead of manganous sulfate. The reaction product gave off a very strong animal-like odor. No hydrazine was found present in the analysis of the reaction product.

B. Oxamide

The original work was undertaken once again with oxamide using the catalyst method for the production of hydrazine from urea.

Runs 41, 42

Reagents	Oxamide	NaOCl	NaOH	H ₂ O	Catalyst
Mole Ratio	1	1	2.66	8320	MnSO ₄
Moles	0.00091	0.00091	0.0024	11.1	1
Weight	0.08gm.	0.063gm.	0.082gm.	200gm.	

Run 41

In this case, oxamide was treated similarly to urea in run 31. The amount of water was greatly increased to compensate for the insolubility of oxamide. Analysis of the product obtained showed that no hydrazine was formed.

Run 42

This reaction was similar to #41 but they differed in that reaction times were increased widely to compensate for the large dilution with water encountered in this case. The times used here were approximately eight hours at each temperature. No hydrazine was produced in this manner.

Run 43

Reagents	Oxamide	NaOCl	NaOH	H ₂ O	Catalyst
Mole Ratio	1	1	2.66	8320	2

In this reaction the method of run 41 was used in general. The one difference was that the catalyst concentration was doubled. This run did not produce hydrazine.

IV. Hofmann degradation of amides according to the modified standard procedure.

A. Oxamide

Here the method of run #11 was used in general. However, run #11 had to be modified with respect to the amount of water and the use of catalyst.

Runs 44, 45

Reagents	Oxamide	NaOCl	NaOH		H ₂ O		Catalyst
Mole Ratio	1	2	(1) 4.5	(2) 3.5	(1) 8320	(2) 30	MnSO ₄ 1
Moles	0.00091	0.00182	0.0041	0.0032	11.1	0.273	
Weight (gm.)	0.08	0.126	0.164	0.127	200	5.0	

Run 44

In this run the amount of water was greatly increased to compensate for the insolubility of oxamide. The table indicates that the reaction was run in two steps the same as run #11. No hydrazine was found present on analysis.

Run 45

This reaction was carried out in a manner similar to run #44. However, the reaction times were increased to about eight hours to take care of dilution. This method produced no hydrazine.

Run 46

Reagents	Oxamide	NaOCl	NaOH		H ₂ O		Catalyst
Mole Ratio	1	2	(1) 4.5	(2) 3.5	(1) 8320	(2) 30	2

Run 46

This reaction resembled #44 closely, but here the catalyst concentration was doubled. Still no hydrazine was produced.

Because of the great difficulty encountered with the insolubility of oxamide in water, a better solvent was sought. The solvents tested were as follows: alcohol; alcohol and water; sodium chloride and water; dimethyl formamide; dimethyl formamide and water; ether; phenol; phenol and water; and chloroform. None of these were good solvents for oxamide.

In trying to determine a possible reaction mechanism, the possibility of making the chloramide of oxamide was considered.⁽⁵⁾ This work had to be discontinued because of the insolubility of oxamide in chloroform.

ANALYSIS OF HYDRAZINE

Since the theoretical reaction product in the Hofmann reaction would be hydrazine, it was necessary to find a method for determining the amount of hydrazine produced in a typical reaction. It is possible to isolate derivatives of hydrazine with certain organic or inorganic reagents, but since this method is quite time consuming, a direct analysis⁽¹⁾ would be much more satisfactory. The method of analysis used in this work is described below.

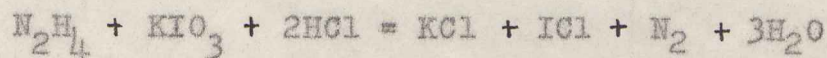
An aliquot portion of hydrazine solution (0.1M) is placed in a 250ml. glass stoppered flask. A volume of concentrated hydrochloric acid is added, 20% in excess of an equal volume of hydrazine sample. Then five ml. of carbon tetrachloride or chloroform is added and the solution is titrated with 0.1M potassium iodate solution made up as a primary standard.

In the titration, as the first few ml. of potassium iodate are added to the titration flask, the inorganic solution becomes brown in color and the organic layer (chloroform) becomes red with the color of the free iodine. As more potassium iodate is added and the end point approaches, the inorganic solution's brown color fades to yellow and the red organic layer becomes pink. Finally, the end point is reached when the color is discharged completely from the organic layer, i.e. when it becomes colorless as it was before the titration.

The amount of hydrochloric acid added before titration is quite important. In any case the solution must have a $[H^+]$ of 6.8 to 7.2 before the titration for best results. In the work that was done with urea, it was necessary to neutralize the hydrazine solution since the hydrazine was produced in a solution approximately 2M with respect to sodium hydroxide. This was accomplished using concentrated hydrochloric acid with Hydrion paper as a pH indicator. After the sample was made to have a pH of 7, concentrated hydrochloric acid was added, 20% in excess of an equal volume of sample. This made the $[H^+] \approx 7$. An example of such a titration is given below.

Run #31 Analysis

The reaction involved here is as follows:



From this equation, we see that 1 mole of hydrazine equals 1 mole of potassium iodate.

A five ml. aliquot portion was withdrawn from the product and neutralized with concentrated hydrochloric acid and diluted to ten ml. Then twelve ml. of concentrated hydrochloric acid and five ml. of chloroform were added to the flask containing the neutralized sample. It was titrated with 17.90 ml. of 0.1000M potassium iodate solution. Since 0.2 mole of urea was used, 0.2 mole of hydrazine could theoretically be produced.

The theoretical yield of hydrazine equals 6.4gm.

$$0.01790 \times .1 = 0.00179 \text{ moles}/\frac{1}{60} \text{ product.}$$

$$0.00179 \times 60 = 0.1074 \text{ moles hydrazine produced.}$$

$$0.1074 \times 32 = 3.43 \text{ gm. hydrazine.}$$

$$\% \text{ yield} = \frac{3.43}{6.4} \times 100 = 53.4\% \text{ hydrazine.}$$

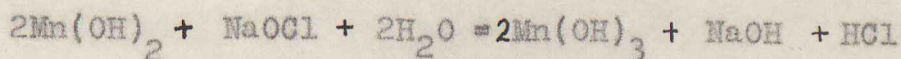
DISCUSSION

It can readily be seen from the experimental data that it was necessary in this work to use a catalyst to produce hydrazine from urea. The exact contribution made by the manganous sulfate is not known, but it is thought that the following reactions take place.

Upon introducing the manganous sulfate into the solution of sodium hypochlorite and sodium hydroxide the following reaction proceeds:



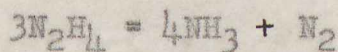
However, Mn(OH)_2 is oxidized to Mn(OH)_3 in the presence of NaOCl as follows:



Mn(OH)_3 is unstable and breaks up to give $\text{MnO} \cdot \text{MnO}_2 \cdot n\text{H}_2\text{O}$

The MnO_2 is the characteristic brown fluffy precipitate.

It is believed that the manganese dioxide serves to tie up any metal ions present and act as an inhibitor, i.e. it inhibits any metal ions catalyzing the decomposition of hydrazine. (4) This decomposition is given below:

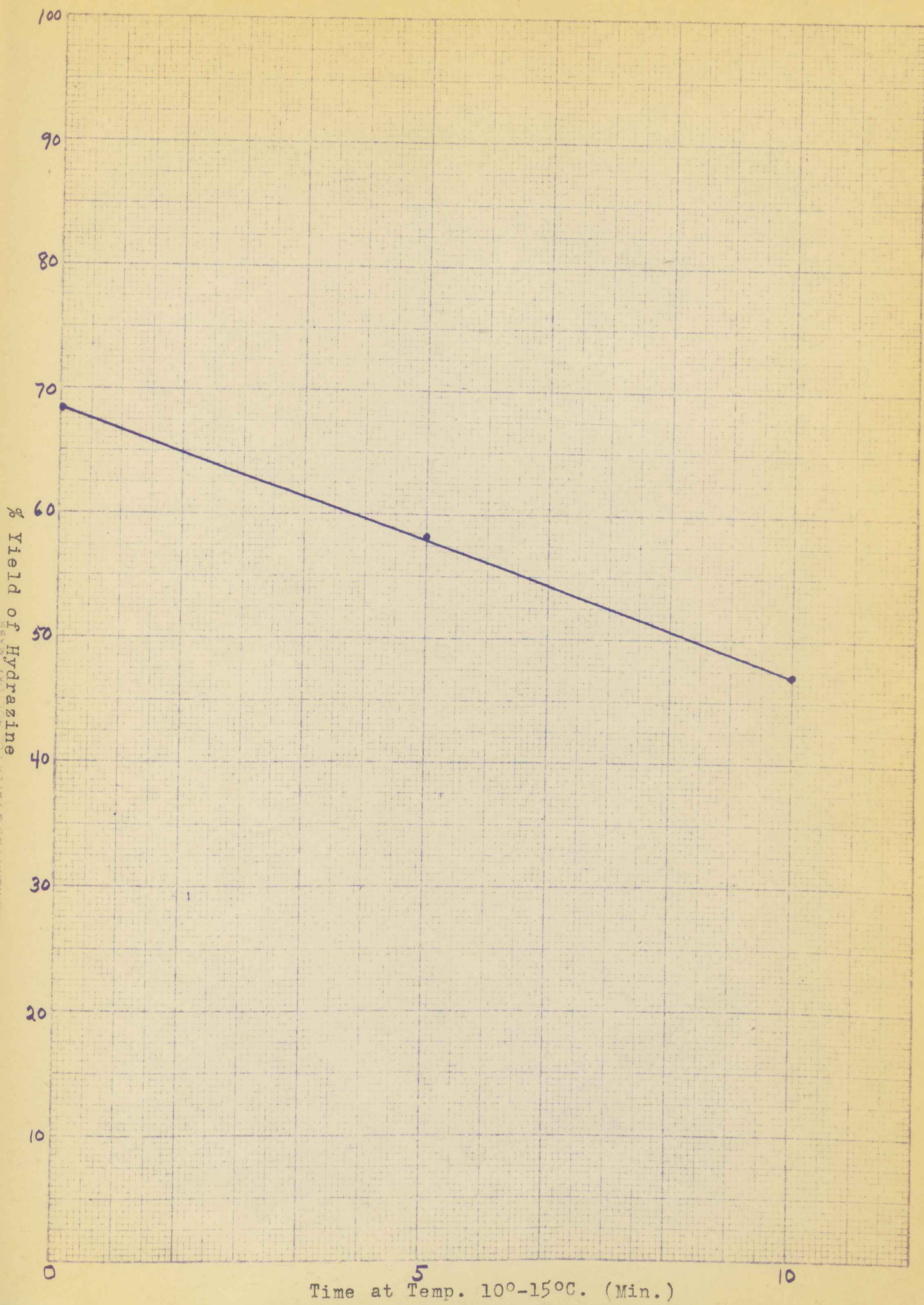


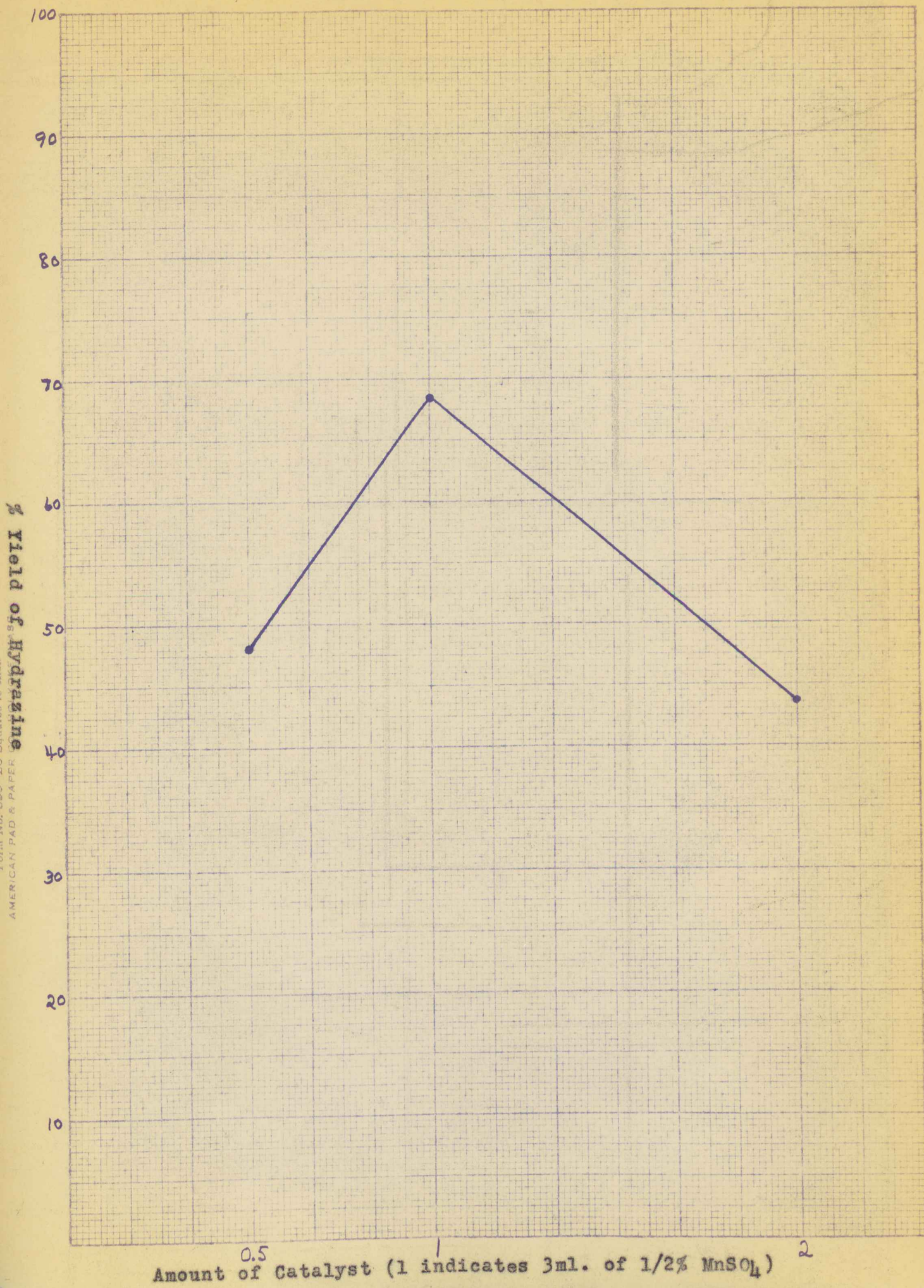
Some of the metals that will catalyze this reaction are copper, iron and steel. It has been reported that glass (not pyrex) will contribute markedly to this effect. For this reason, it is necessary to observe certain precautions while working

with hydrazine. Most important of these is that the apparatus be very clean. Also, the use of a condenser is highly recommended where solutions of hydrazine are to be boiled due to the toxicity of this chemical.

The inability of oxamide to produce hydrazine is demonstrated. Its very low solubility is definitely a hindrance in such a reaction. The reason for this non-reactivity is probably due to the way in which the hydrogen atoms are held on the molecule. These bonds are likely to be very strong considering the interior of the molecule ($\overset{\text{O}}{\parallel}\text{C}-\overset{\text{O}}{\parallel}\text{C}-$).

The graphs included show the optimum conditions for producing hydrazine from urea. The first graph serves to show the effect of time at 10°-15°C; the second demonstrates the effect of varying the catalyst concentration on the reaction.





SUMMARY

The Hofmann reaction was not found suited to degrade oxamide to hydrazine using the normal conditions assumed in the Hofmann reaction for diamides.

It was not possible to produce hydrazine from urea using the method of the first patent⁽⁶⁾. Hydrazine was produced from urea using the method of the second patent⁽⁷⁾ which employed manganous sulfate as a catalyst.

Oxamide would not yield hydrazine in a Hofmann reaction under conditions closely paralleling the urea catalyst method or in the Hofmann reaction of diamides using the same catalyst.

BIBLIOGRAPHY

1. Heineman's Thesis, Union College, 1950.
2. Marzluff's Thesis, Union College, 1947.
3. Rosekran's Thesis, Union College, 1946.
4. Audrieth, Chemistry of Hydrazine, J. Wiley & Sons, 1951, pages 157, 117.
5. Hickenbottom, Reactions of Organic Compounds, Longmans, Green & Co., 1936, page 222.
6. German Patent #Nr.735321, May, 1943.
7. German Patent #Nr.729105, December, 1942.
8. Whelan, Advanced Organic Chemistry, J. Wiley & Sons, 2nd edition, 1949, page 475.