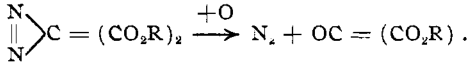
to be evidence of the presence of diazomalonic ester, which, with free oxygen, would give nitrogen gas and oxomalonates,



$$\overset{N}{\underset{N}{\|}}\!\!>\!C = (CO_2R)_2 \xrightarrow{+O} N_2 + OC = (CO_2R)\ .$$

Diazomalonic ester has long been sought but without success. Our time was insufficient to investigate these neutral nitrogenous esters.

Mr. Roarke found that the ethereal filtrate, from the crude ammonium salts above mentioned, contains a substance which was obtained by the evaporation of the ether to dryness, and recrystallization of the yellow residue, from benzene-ligroin, and from carbon tetrachloride. The substance was obtained as flat, colorless needles, highly refractive, flexible and greasy to the touch. It melted at 50°, to a yellow liquid. The analysis follows:

C, 41.29, 41.35; H, 8.05, 8.60; N, 16.04, 16.14.

This same product was obtained, by distilling the "crude oils" washed with water, and was found in the fraction of b. p. 97° at 32–34 mm. (uncor.). It is easily soluble in ether, alcohol, acetone, carbon tetrachloride, chloroform, and fairly soluble in benzene and ligroin. It has not been further studied.

URBANA, ILL.

[CONTRIBUTION FROM THE CHEMICAL LABORATORIES OF CLARK UNIVERSITY, WORCESTER, MASS.]

THE PREPARATION OF ACETAMIDE.

BY M. A. ROSANOFF, LOUISE GULICK, AND HERBERT K. LARKIN.

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Methods Used Hitherto.—Acetamide has long been prepared by the action of aqueous ammonia upon ethyl acetate, as originally proposed by Dumas, Malaguti and Leblanc.[1] The reaction mixture has no effect upon iron, and so the process can be carried out on a considerable scale in iron autoclaves.

The preparation of amides from the ammonium salts of the corresponding acids was first introduced by Dumas.[2] The details of this method, as now generally employed for the preparation of acetamide on a laboratory scale, were worked out by Hofmann.[3] Hofmann sums up the condition of the preparative method at the time he undertook its amelioration, in the following words:

"If, however, the preparation of amides hy treating esters with ammonia leaves much to be desired, the yields obtained by the distillation of ammonium salts are even less satisfactory. Experiments on the prepara-

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[1] *Comptes rendus*, 25, 657 (1847).

[2] *Ann. chim. phys.*, [2] 44, 142, (1830).

[3] *Ber.*, 15, 977 (1882).

tion of acetamide by this method have been published by Kündig,[1] who obtained, in the most favorable case, using glacial acetic acid saturated with ammonia gas, something over 25 per cent. of the theoretical yield. In all these distillations streams of ammonia escape at first, which naturally reduces the yield of amide. Petersen,[2] who, at Bunsen's suggestion, modified the experiment by distilling a mixture of equivalent quantities of fused sodium acetate and sal ammoniac, states that acetamide may thus be easily and advantageously prepared, but says nothing concerning the percentage yield. When this experiment was repeated, perfectly pure acetamide was obtained directly, but in this case, too, a large quantity of ammonia was lost and the final yield of acetamide amounted to only 20 per cent. of theory."

Hofmann's method, as given in its optimum form by Gattermann,[3] consists in neutralizing 75 grams of acetic acid with ammonium carbonate and heating in sealed tubes for five hours at 225°. The reaction product is subjected to fractional distillation; the fraction passing over between 180° and 230° is collected separately and on solidification pressed out on a drying-plate. The pressed-out crystals are redistilled, yielding about *40 grams* of almost pure acetamide.

This operation, however, cannot be carried out on a large scale. We quote from Hofmann[4]: "Unfortunately, this operation cannot be carried out, like the treatment of esters with ammonia, in iron autoclaves, as these are strongly attacked. Acetamide will, therefore, be best prepared in the future, as heretofore, by treating the ester with ammonia at ordinary temperatures."

One or two modifications of the Hofmann method have been proposed since 1882. Thus, Schultze[5] warms ammonium acetate with acetic anhydride, using no less than 130 grams of anhydride to 100 grams of the acetate. This, however, is not only costly, but unquestionably yields much diacetamide together with acetamide. Keller[6] distils ammonium acetate in a current of ammonia. We have tried out this method, but with no satisfactory results: unless one carries out a great many redistillations, which is disproportionately laborious, the yield is very small (generally about 12 per cent. of the theory).

New Method.—Hofmann's method has two disadvantages: first, the acetate must be heated in sealed vessels; secondly, iron vessels cannot be employed.

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[1] *Ann.*, 105, 277 (1858).

[2] *Ibid.*, 107, 331 (1858).

[3] "The Practical Methods of Organic Chemistry," trans. by Schober (New York, 1907).

[4] *Loc. cit.*, p. 981.

[5] *J. prakt. Chem.*, 27, 512 (1883).

[6] *Ibid.*, 31, 364 (1885).

From the viewpoint of chemical statics, there is very little advantage in raising the temperature to 220°. According to Menschutkin,[1] the maximum percentages of acetamide formed at different temperatures are as follows:

Temperature.	Maximum per cent. acetamide formed.	Temperature.	Maximum per cent. acetamide formed.
125.0°	75.1	182.5°	82.8
140.0	78.2	212.5	84.0
155.0	81.5		

Obviously, almost as much acetamide could be obtained at 140° as at 220°. The reason that the higher temperature is generally employed is that at lower temperatures the reaction is impracticably slow.

This suggested the possibility of rendering the old method simple and convenient by employing *a suitable catalytic agent.*

The most appropriate catalyst, apparently, was suggested by the following simple considerations. From the fact that the hydrolysis of amides is catalyzed by acids, the inference was drawn that acids would also hasten the opposit reaction, *i. e.*, amide formation. Mineral acids could not be used, as they would take up the ammonia from the ammonium acetate. Organic acids generally would yield their own amides in addition to acetamide. *Acetic acid alone could do no harm and might be confidently expected to promote the reaction catalytically.*

Theoretically it was also clear that, by increasing the volume of the reacting mixtures, the acid catalyzer would improve the yield, since the reaction involves the formation of two molecules (amide and water) from a single molecule (ammonium acetate). This might be expected to counterbalance the slight diminution of yield produced by the temperature lowering.

Experiment soon showed that in the presence of an excess of acetic acid the amide formation really took place with considerable velocity in open vessels. It remained to determin the essential details of the preparation, and this required a large number of trials. The following directions will be found to yield satisfactory results.

First, good dry ammonium acetate is prepared by neutralizing glacial acetic acid with pulverized ammonium carbonate at about 50°, allowing to cool, draining off the crystals, and pressing them out twice or three times with filter paper. The product so obtained contains very nearly 98 per cent. of the pure salt.[2]

100 grams of this ammonium acetate (corresponding to 75 grams of acetic acid) and 113 grams glacial acetic acid (ratio: 1 mol. acetate to

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[1] *J. prakt. Chem.*, 29, 445 (1884).

[2] The use of ammonium acetate freed from water is best for the obvious reason that water promotes hydrolysis of the amide and hence necessarily diminishes the yield. Commercial ammonium acetate contains more of less free acid and is unreliable, unless neutralized and pressed out afresh.

1.5 mols. acid) are boiled in a one-liter flask with reflux condenser for 5 hours. The product is rapidly distilled over with minimum loss[1] and subjected to fractionation (again out of a 1-liter flask) with the aid of a two-bulb Wurtz stillhead. *This operation should be carried out as slowly as possible.* Three fractions are collected separately: (1) the fraction passing over below 180°; (2) the fraction passing over between 180° and 213°; (3) the fraction passing over above 213°. During the distilling of fraction 3 the stillhead is unnecessary. The second fraction (180°-213°) is slowly redistilled with the Wurtz stillhead, and the portion passing over above 213° is added to fraction 3, the remainder being added to fraction 1. The original product is thus divided into a low-boiling and a high-boiling fraction. The former may again be neutralized with ammonium carbonate and the resulting salt used for a new preparation. The high-boiling fraction, on thorough solidification, is twice pressed out with filter paper. The dry crystals (practically pure acetamide) weigh *over 60 grams*, or 20 grams more than the product obtained by the use of sealed tubes according to the Hofmann-Gattermann directions. The yield is, however, slightly variable, depending on the quality of the ammonium acetate used and especially on the care with which the fractionation is carried out.[2]

It is obvious that the above directions permit of transforming ammonium acetate into acetamide on as large a scale as may be desired, and should lead to a considerable reduction of the present price of acetamide.

In order to make certain that the low temperature employed did not after all materially diminish the yield, some experiments were carried out on the following plan: 100 grams of our fairly dry ammonium acetate and 113 grams of acetic acid were heated for 3 hours (experiments have shown that even 2 hours would have sufficed) at 225° in sealed tubes. The product was subjected to fractional distillation as described above. The yield was about 56 grams. There is, certainly, no advantage in using sealed tubes.

Our product boils at 214-216°, which shows it to be nearly pure acetamide.

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[1] This distillation materially improves the yield.

[2] In two consecutive preparations carefully carried out in this laboratory by Mr. H. R. Godfrey, the yield was, respectively, 62 and 63.5 grams. At the suggestion of Professor William A. Noyes, Mr. Godfrey was also requested to try the preparation of acetamide from ammonia and an excess of acetic acid directly, without isolating the ammonium acetate. Dry ammonia gas was introduced into 188 grams Kahlbaum's glacial acetic acid (= 75 grams + 113 grams excess, as above) until the increase in weight amounted to 21.3 grams. This was changed to acetamide according to our directions. Two such consecutive trials yielded, respectively, 63.3 grams and 62.2 grams acetamide. The simplification will be valuable when only one preparation is to be carried out.