7. A second amino group in a compound already containing one amino and two carboxyl groups, or a second carboxyl group in a compound already containing one carboxyl and two amino groups does not appear to increase the promoter effect.

8. α-Amino acids with a nitrogenous heterocycle give, on the average, a somewhat greater promoter effect than simple α-amino acids.

9. There is some indication that in aliphatic α-amino acids the promoter effect decreases with lengthening carbon chain.

10. In α-amino acids, optical isomers do not differ in promoter effect.

11. Ammonium chloride has no promoter action when changes in hydrogen-ion concentration are eliminated and correction is made for the ammonia it contains. Thus the favorable effect of ammonium chloride reported by others[1a] is not the specific effect demonstrated in this investigation.

12. From the results of our work it appears that the effect of a compound on the activity of urease may furnish valuable presumptive evidence as to the presence of an amino group in the α position to carboxyl.

13. The experiments which show the promoter action of α-aminocarboxylic acids and of peptones indicate that the protein part of enzyme preparations is an important factor in the action of the enzyme because its promoter action accounts for part of the activity of the enzyme.

14. The experiments tend to disprove the hypothesis that the promoter effect is due chiefly to prevention of decomposition of the enzyme. On the other hand, the results support the view that the promoters directly facilitate the interaction of the enzyme with the substrate.

IOWA CITY, IOWA

[CONTRIBUTION FROM THE LABORATORIES OF GENERAL CHEMISTRY, UNIVERSITY OF WISCONSIN]

A NEW METHOD FOR THE DETERMINATION OF ACETIC ACID IN ACETIC ANHYDRIDE

BY JAMES H. WALTON AND LLOYD L. WITHROW

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Acetic anhydride has become so important a reagent in organic synthesis, that a rapid and accurate method for determining its chief impurity, acetic acid, is very desirable. In a recent investigation by E. R. Schierz[1] and the senior author of this paper a method for determining this substance was indicated.

When formic acid is added to acetic anhydride, it is broken up quantitatively according to the equation $HCOOH = H_2O + CO$. At ordinary temperatures the reaction proceeds so slowly that it is practically unmeasurable. It was found by Schierz that this reaction is catalyzed by

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[1] Schierz, THIS JOURNAL, **45**, 455 (1923).

the following tertiary nitrogen bases which are listed in the order of decreasing activity: strychnine, brucine, nicotine, cocaine, pyridine, morphine, quinine.

In the presence of small amounts of acetic acid the catalytic activity of certain of these compounds was greatly reduced. Since the retardation was found to be proportional to the concentration of the acetic acid it was thought that this effect could be used as the basis of a method for determining small amounts of acetic acid in acetic anhydride. It was planned to prepare pure acetic anhydride and measure the rate of decomposition in the presence of a given concentration of catalyst. The rate of decomposition in the presence of various concentrations of acetic acid could then be determined, and these data used to plot a curve showing the effect of acetic acid on the catalytic decomposition of formic acid. A solution of acetic anhydride could then be analyzed by adding the proper amounts of formic acid and catalyst, measuring the velocity of decomposition and reading on the curve the percentage of acetic acid corresponding to the velocity constant obtained.

Acetic Anhydride.—A commercial preparation labeled 97% was used for the preparation of the pure anhydride. To remove the acetic acid this material was allowed to stand in contact with thin slices of metallic sodium for several days. The mixture was then refluxed under reduced pressure for several hours and was finally distilled from a mixture of metallic sodium and sodium acetate. The latter substance aids in the retention of any free acetic acid that might still be present. On distilling the acetic anhydride the first portion that came over was greenish. This was discarded. The latter portion distilled at a constant temperature. Its physical constants, stated below, compare favorably with those given by Orton and Jones:[2] b. p., 139.3 (740 mm.); d^{25}, 1.0765; n_D^{25}, 1.3885; n_D^{31}, 1.3863. Further evidence of the purity of this anhydride is the fact that when frozen in liquid air it congealed without clouding. When anhydride of 98.7% purity was frozen, crystals of acetic acid separated at —50°. The anhydride prepared by the method described above melted at —86°.

This anhydride was tested for the presence of acetaldehyde by the method of Stepp and Frick.[3] Approximately 0.1% was found present. Acetone was absent.

Strychnine.—Commercially pure strychnine was recrystallized from ethyl alcohol and dried at 100°.

Formic Acid.—An 85% solution was dehydrated at 50° with anhydrous oxalic acid. The solution was then cooled and the crystals of oxalic acid were filtered off. Upon distillation a very concentrated solution was obtained. This was dehydrated with boric acid and distilled,[4] a product practically 100% pure being obtained.

Apparatus.—The velocity of decomposition of the formic acid was determined by placing the reaction mixture in a flask containing some pieces of glass rod, shaking it vigorously to avoid supersaturation, and measuring the rate of evolution of gas by collecting it over water in water-jacketed burets.[5] The catalyst and anhydride were first placed in the flask. The formic acid was placed in a capsule held in the neck of the flask

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[2] Orton and Jones, *J. Chem. Soc.*, **101**, 1720 (1912).

[3] Stepp and Frick, *Z. physik. Chem.*, **116**, 233 (1921).

[4] Schlesinger and Martin, THIS JOURNAL, **36**, 1589 (1914).

[5] Walton, *Z. physik. Chem.*, **47**, 185 (1904).

in such a manner that it could be dropped whenever desired. The reaction takes place very slowly at room temperature, so all determinations were made at 35°. It was shown by Schierz that this reaction is monomolecular.

Results.—Table I summarizes a typical run made with the pure anhydride, formic acid and catalyst. In this experiment, as in all others made in this investigation, 25 cc. of acetic anhydride, 0.25 g. of strychnine (catalyst) and 0.07 cc. of formic acid were used in each experiment. This amount of formic acid gives about 35 cc. of carbon monoxide measured at 0° and 760 mm. In this table, *T*, *X*, *A* and *K* have their usual significance in the formula for a reaction of the first order.

Table I

The Decomposition of Formic Acid in Pure Acetic Anhydride Using Strychnine as Catalyst

T	X	$A-X$	K
1.5	18	19.8	0.437
2	22.3	15.7	.440
2.5	25.8	12.2	.452
3	28.2	9.8	.450
3.5	29.2	8.8	.421
4	31.8	7.2	.415
5	34	4.0	.436
A = 38.00			Av. .434

Repeated: K = 0.425 and 0.487

It will be noted that this experiment was extremely rapid, the reaction being almost 90% complete in 5 minutes. Taking this fact into consideration, the agreement of the constants is satisfactory. The acetic anhydride used in each of the experiments was purified and freshly distilled for that particular experiment. It is believed that no one of these samples contained more than a slight trace of acetic acid.

Since the acetic anhydride contains a small amount of aldehyde the influence of the presence of this substance on the rate of the reaction was investigated. When present to the extent of 5% in a sample of acetic anhydride containing a small quantity of acetic acid it changed the velocity constant from 0.320 to 0.315; the effect can consequently be neglected. Schierz showed that the rate of the reaction is not influenced by the presence of small quantities of ketones or aromatic aldehydes.

A number of experiments were carried out to determine the effect of various concentrations of acetic acid on the velocity of this reaction. Since the rate of decomposition in the presence of acetic acid is slower, more concordant results than those listed in Table I were obtained. Because of the extreme slowness of the reaction, concentrations of acetic acid greater than 5% were not used. The results of the experiments are given in Table II and are shown graphically in Fig. 1.

These results indicate that wherever the analysis of acetic anhydride for acetic acid is a part of the routine work this method will be found satisfactory. It is extremely rapid and sufficiently accurate for most purposes. For determining the presence of very small amounts of acetic acid the method can be improved by carrying out the experiment at 25°; at this temperature the reaction would be almost half as fast and the velocity could be measured more accurately. For higher concentrations of acetic acid than 5% a temperature of decomposition higher than 35°

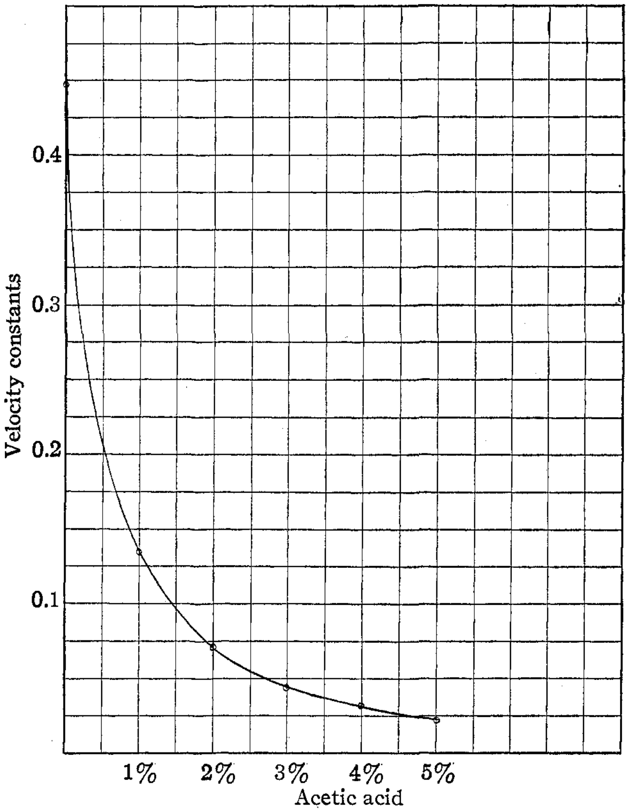

Fig. 1.—The influence of acetic acid on the catalytic decomposition of formic acid

TABLE II

THE EFFECT OF ACETIC ACID UPON THE RATE OF DECOMPOSITION OF FORMIC ACID IN ACETIC ANHYDRIDE SOLUTION

Concn. of acid %	K	$K_{\text{dup.}}$	$K_{\text{av.}}$	K concn. acid
0	...	...	0.447	...
1	0.134	0.135	0.135	0.135
2	.0664	.0689	.677	.135
3	.0468	.0467	.468	.140
4	.0334	.0319	.327	.130
5	.0236	.0238	.237	.119

could be used or the solution diluted with enough pure acetic anhydride to bring the concentration of the acetic acid to approximately 5%.

The last column of Table II shows that when from 1 to 4% of acetic acid is present the value [Velocity constant × concn. acetic acid] equals a constant. In other words the retardation of this reaction is directly proportional to the concentration of acetic acid. When more acetic acid is added this relationship does not hold.

Summary

1. A method for preparing acetic anhydride of a high degree of purity is described and certain physical properties of the anhydride have been determined.
2. The effect of different concentrations of acetic acid upon the rate of decomposition of formic acid in acetic anhydride solution, using strychnine as a catalyst, has been determined. This forms a basis for the quantitative analysis of acetic anhydride for acetic acid when 1 to 5% of this impurity is present.

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[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF IOWA STATE COLLEGE]

STUDIES CONCERNING THE DIRECT PREPARATION OF ORGANOBERYLLIUM HALIDES[1]

BY HENRY GILMAN

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Introduction

Much of the importance of organometallic compounds in synthetic work is confined to those compounds formed from metals of the second group of the periodic system. Zeltner,[2] from a study of many organometallic compounds, has called attention to two apparently general rules concerning the reactivity of such compounds which have each of the ordinary valences of the metal satisfied by an alkyl or aryl group. First, in a given group of metals having the same radicals attached to the metal, that organometallic compound with the metal of lowest atomic weight is most reactive. Second, with a given metal, that organometallic compound which has the lightest radicals is most reactive.

If these generalizations are true, it follows that one should expect an organoberyllium compound having alkyl groups of low molecular weight to be most reactive in a group which already contains several organometallic types of high reactivity. If organoberyllium halides could be prepared and if they should exhibit this reactivity, they might make pos-

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[1] An abstract of a paper presented at the Intersectional Meeting of the American Chemical Society held at Urbana, Illinois, May 5, 1923.

[2] Zeltner, *J. prakt. Chem.*, **77**, 393 (1908).