into cold water the hydantoin separated. It was purified by recrystallization from dilute alcohol and spearated in the form of balls of microscopic crystals. The compound melted from 180–185° and gave a positive test with Millon's reagent. It was dried for analysis at 110°.

Calc. for $C_{12}H_{13}O_5N_3$: N, 15.06. Found: N, 15.22, 15.20.

2-Thio-4-anisalhydantoin (XXVI).—Johnson and O'Brien[1] first prepared this compound by condensing 2-thio-3-benzoylhydantoin with anisic aldehyde and finally hydrolyzing the resulting benzoyl derivative with hydrochloric acid. The same compound was prepared for our work by condensing 2-thiohydantoin with anisic aldehyde in acetic acid solution and in the presence of sodium acetate. From 23 g. of the 2-thiohydantoin we obtained 45 g. of the anisal compound. It was crystallized from glacial acetic acid and melted at 260°.

Calc. for $C_{11}H_{10}O_2N_2S$: N, 11.96. Found: N, 11.95.

2-Thio-4-anisylhydantoin (XXIX).—The hydantoin was prepared by reduction of the above anisalhydantoin (XXVI) with sodium amalgam. The procedure was as follows: Five grams of the unsaturated hydantoin were suspended in a solution of 65 cc. of water and 10 cc. of dilute sodium hydroxide and then 100 g. of 3% sodium amalgam added in small portions at a time. The temperature was kept at 75°. After the amalgam had been added the solution was then filtered and acidified with hydrochloric acid, when the hydantoin separated in a crystalline condition. The yield of crude material was 4.5 g. In order to destroy any hydantoic acid present this material was suspended in hydrochloric acid and the mixture heated on the steam bath. The acid was finally completely evaporated and the hydantoin purified by crystallization from acetic acid. It separated from this solvent in plates and melted at 215°.

Calc. for $C_{11}H_{12}O_2N_2S$: N, 11.87. Found: N, 12.0, 11.92.

NEW HAVEN, CONN.

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE UNIVERSITY OF TEXAS.]

THE USE OF CYANIC ACID IN GLACIAL ACETIC ACID SOLUTION, AND IN MIXTURES OF GLACIAL ACETIC ACID WITH OTHER ORGANIC SOLVENTS. DERIVATIVES OF 1-ISOBUTYRIC ACID AMINO-5-DIMETHYLHYDANTOIN.

BY J. R. BAILEY AND W. T. READ.

Received June 12, 1915.

Introduction.

As is well known, many reactions in organic chemistry have been found to proceed most smoothly in glacial acetic acid, and this cannot, in every

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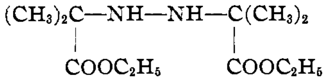
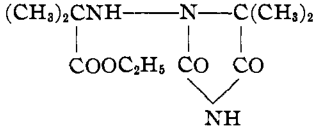
[1] *Loc. cit.*

instance, be ascribed to the mere fact that the glacial acetic acid is a better solvent than other media for the reacting constituents. Water-free acetic acid is beyond doubt in many cases a direct catalyst. In the work herein described, the observation has been made that cyanic acid does not react with ethyl hydrazoisobutyrate

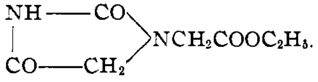


$$\begin{array}{ccc}(\mathrm{CH_3})_2\mathrm{C} & \text{—NH—NH—} & \mathrm{C(CH_3)_2}\\ | & & | \\ \mathrm{COOC_2H_5} & & \mathrm{COOC_2H_5}\end{array}$$

in water solution, but in glacial acetic acid, the two substances at room temperature condense readily with the formation of the ethyl ester of 1-isobutyric acid amino-5-dimethylhydantoin,



Bailey and Snyder[1] carried out "experiments without result to convert iminoacetonitrile, $NH(CH_2CN)_2$, to its ureido derivative in the usual way by the action of potassium cyanate on the hydrochloride of this amine in water solution." On the other hand, "by treatment of iminoacetonitrile in glacial acetic acid with potassium cyanate, saponification of the ureido derivative thus formed, and then esterification," they obtained ethyl hydantoin-1-acetate,



The use of glacial acetic acid as a solvent in effecting the condensation of cyanic acid with benzylidene hydrazones is discussed further on.

A careful survey of the literature has not revealed the use of glacial acetic acid by any previous investigators as a solvent for cyanic acid, although this solvent is frequently used in connection with isocyanates and mustard oils.

Adolf Sonn[2] has recently announced a valuable method of preparation of substituted ureas, which consists in heating primary amines with urea or mono-substituted ureas in glacial acetic acid solution. He states that "in place of urea, ammonium sulfocyanide can be used," and describes the preparation of diphenyl urea by heating aniline with ammonium sulfocyanide in glacial acetic acid. However, at the time of the publication of Sonn's article, the work described by us had been practically completed.

Ordinarily, the addition of cyanic acid on both primary and secondary amines proceeds smoothly in water solution, and in such cases the use

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[1] This Journal, 37, 940 (1915).

[2] *Ber.*, 47, 2437 (1914).

of glacial acetic acid is of course not to be recommended; but it may be that this modification of the urea synthesis will find further application in cases similar to the ones cited above, where the addition of cyanic acid takes place with difficulty, if at all, in water. Furthermore, experiments are being conducted in this laboratory toward an extension of the condensations of cyanic acid with glacial acetic acid as the reacting medium.

As a number of common organic solvents are miscible with glacial acetic acid, experiments were instituted with mixtures of acetic acid with chloroform, benzene, and absolute alcohol as media for effecting the condensation of cyanic acid with ethyl hydrazoisobutyrate. It was found that these substitutes for glacial acetic acid, within certain limits at least, were as effective as the acetic acid itself, so that in all probability the use of these mixed solvents will find application in certain cases where their solvent action is greater than that of the simple glacial acetic acid. Furthermore, in working with ethyl hydrazoisobutyrate, it was found that the addition of cyanic acid takes place in an aqueous acetic acid where the percentage of the acetic acid is above thirty. However, the yield of the desired reaction product is far below that obtained in a medium of glacial acetic acid. It appeared possible that an excess of mineral acid might serve the same purpose as the glacial acetic acid, but it was observed that in aqueous solution, no reaction takes place between cyanic acid and ethyl hydrazoisobutyrate, either when the calculated amount of hydrochloric acid or one mol in excess is employed.

Knorr and Köhler[1] have shown that cyanic acid reacts with hydrazomethane in water solution, forming dimethylsemicarbazide,

$$NH_2CON(CH_3)NHCH_3,$$

which, as far as our information goes, was the first observed instance of a hydrazo compound behaving like a secondary amine towards cyanic acid. Researches carried out in this laboratory[2] have shown that hydrazo acids readily condense with mustard oils and isocyanates, forming substituted hydantoins; but as a rule hydrazo bodies do not react readily with mustard oils,[3] although they react more readily with isocyanates.[4]

As stated above, cyanic acid and ethyl hydrazoisobutyrate react in molecular proportions in glacial acetic acid with the formation of the ethyl ester of 1-isobutyric acid amino-5-dimethylhydantoin. The constitution of this addition product of cyanic acid on ethyl hydrazoisobutyrate was established beyond question by its conversion to 1-amino-5-dimethylhydantoin, and the synthesis of the latter compound from

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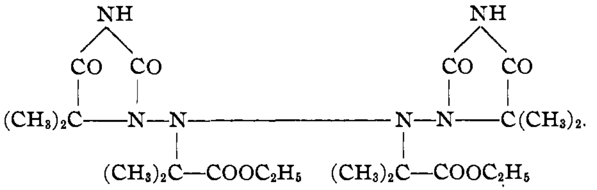
[1] *Ber.*, **39**, 3263 (1906).

[2] THIS JOURNAL, **26**, 1006 (1904).

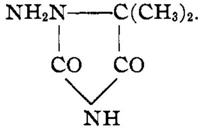
[3] *Ber.*, **25**, 3115 (1892).

[4] *Ibid.*, **23**, 490 (1890).

hydrazinoisobutyric acid. The ester of the isobutyric acid aminodimethylhydantoin is readily oxidized in the cold, bromine water, for example, giving in quantitative yield a nonvolatile oil, for which we have tentatively assigned the formula



It, furthermore, behaves as a secondary amine toward nitrous acid in the formation of a stable nitroso compound. Heated with sulfuric acid, the isobutyric acid aminohydantoin ester hydrolyzes to 1-amino-5-dimethylhydantoin,



The hydrazine character of the latter substance is shown in its ready condensation with benzaldehyde.

As a definite proof of the constitution of the reaction product of sulfuric acid on the ester of isobutyric acid aminodimethylhydantoin as 1-amino-5-dimethylhydantoin, the synthesis of this substance from hydrazinoisobutyric acid[1] and cyanic acid was attempted. However, here the cyanic acid adds to the β-nitrogen, forming semicarbazinoisobutyric acid,

$$HCl.NH_2NHC(CH_3)_2COOH + KCNO = NH_2CONHNHC(CH_3)_2COOH + KCl.$$

A similar action of cyanic acid was observed by Darapsky and Berger[2] in the preparation of ethyl semicarbazinobenzylacetate,

$$NH_2CONHNHCH(CH_2C_6H_5)COOC_2H_5,$$

whereas Darapsky and Prabhakar[3] found that ethyl hydrazinophenylacetate and cyanic acid give an addition product with the carbonamide rest on the α-nitrogen, of the following constitution:

$$NH_2N(CONH_2)CH(C_6H_5)COOC_2H_5$$

W. Traube and Hoffa[4] have made the interesting observation that ethyl hydrazinoacetate yields both of the possible ureido derivatives:

$$NH_2CONHNHCH_2COOC_2H_5 \text{ and } NH_2N(CONH_2)CH_2COOC_2H_5$$

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[1] *Ann.*, **290**, 17 (1896).

[2] Dissertation (Heidelberg), **1912**.

[3] *Ber.*, **45**, 1658 (1912).

[4] *Ibid.*, **31**, 162 (1898).

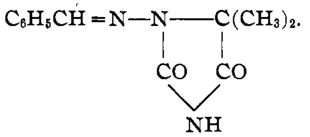
Phenylhydrazine condenses in a similar way with phenyl mustard oil,[1] giving two products of the constitution:

$$C_6H_5NHNHCSNHC_6H_5 \text{ and } NH_2N(CSNHC_6H_5)C_6H_5$$

An interesting method of preparing α-ureido derivatives of hydrazino acids, available where they cannot be prepared by the direct action of cyanic acid on the hydrazino acids, is described in the experimental part of this article, which method starts with the addition of cyanic acid on benzylidene hydrazino acids. For example, benzylidene hydrazinoisobutyric acid,

$$C_6H_5CH = N — NHC(CH_3)_2COOH,^2$$

reacts readily in glacial acetic acid with cyanic acid, yielding 1-benzylidene amino-5-dimethylhydantoin,



Attempts to effect this reaction in aqueous solution failed. The benzylidene compound of the aminodimethylhydantoin can be easily hydrolyzed, forming the corresponding aminodimethylhydantoin, identical with the reaction product of sulfuric acid on the ethyl ester of 1-isobutyric acid amino-5-dimethylhydantoin. Busch and Walter[3] employed a method similar to the one followed above to obtain α-phenylsemicarbazide,

$$C_6H_5N(CONH_2)NH_2,$$

from benzylidene phenylhydrazine,

$$C_6H_5CH = N — NHC_6H_5.$$

However, the intermediary benzylidene-α-phenylsemicarbazide, according to our observations, cannot be prepared by the modified Wöhler synthesis used by us in the case of benzylidene compounds of hydrazino acids. Busch obtained his ureido compound by treating benzylidene phenylhydrazine with carbonyl chloride, and the resulting benzylidene phenylhydrazinecarboxylic acid chloride,

$$C_6H_5N(COCl)N = CHC_6H_5,$$

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[1] *Ber.*, **34**, 321 (1901).

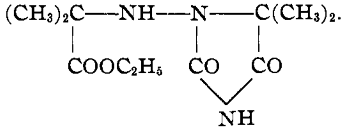
[2] By J. R. Bailey and L. A. Mikeska: The benzylidenehydrazinoisobutyric acid used in the above experiment was obtained by treating a hydrazine solution with one mol of acetone, adding sodium bisulfite on the resulting hydrazone (*Ber.*, **37**, 4073 (1904); THIS JOURNAL, **37**, 936 (1915)) replacement of the sulfonic acid rest by the CN group, saponification of the resulting nitrile, and treatment of the hydrazino acid thus formed with benzaldehyde. This method of preparation of benzylidene hydrazinoisobutyric acid, and consequently of hydrazinoisobutyric acid itself, is to be preferred in point of simplicity to the method of Thiele and Heuser (*Ann.*, **290**, 15 (1896)) where, although the yields are excellent, the procedure is complicated by the number of steps involved and the time required for their completion.

[3] *Ber.*, **36**, 1359 (1903).

with ammonia. Attention is directed to the fact that the cyanic acid reaction with the benzylidene compounds of hydrazino acids, apart from its preparative value, may be used to characterize hydrazino acids.

Experimental Part.

Preparation of the Ethyl Ester of 1-Isobutyric Acid Amino-5-Dimethylhydantoin,



$$\underset{COOC_2H_5}{(CH_3)_2C}-NH-\underset{CO}{N}-\underset{CO}{C}(CH_3)_2.\quad \text{CO}\diagdown\!\diagup\text{CO}: NH$$

—35 g. of ethyl hydrazoisobutyrate, prepared according to the method of Thiele and Heuser,[1] are dissolved in 70 cc. of glacial acetic acid, and then a slight excess of solid potassium cyanate, 18 g., added in small portions during an interval of forty-five minutes, the temperature being kept below 40°. The reaction at first proceeds without gas evolution; but at the end of one hour the temperature of 60° is maintained in the solution for thirty minutes, during which time there is some gas evolved. Potassium cyanate, when dissolved in pure glacial acetic acid, gives off carbon dioxide quite vigorously, even when the temperature is kept below 40°. To isolate the reaction product, the acetic acid solution is diluted to three times its volume, and the acid neutralized with ammonia, while the container is immersed in ice-water. The larger part of the hydantoin compound crystallizes out, and a further small amount can be obtained by extraction with chloroform. The yield is about 86% of the theoretical. The new substance is readily soluble in the common organic solvents, petrolic ether excepted. For analysis it was crystallized from a benzene-petrolic ether mixture, and finally from 50% alcohol. From the latter solvent it can be obtained in plates resembling rhombic prisms. The substance melts at 104–105°. It does not dissolve in dilute mineral acids in the cold, but slowly dissolves in 50% sulfuric acid on heating with the elimination of the isobutyric acid rest. Even in the cold it reduces bromine water instantaneously and permanganate slowly. In the preparation of the above isobutyrica cid aminodimethylhydantoin ester it is possible within certain limits to use mixtures of glacial acetic acid with various organic solvents without materially affecting the yield, and it was further observed that the reaction also takes place in aqueous acetic acid of a concentration above 30%, but with diminished yield depending, no doubt, on the amount of water present. Our attempts to condense hydrazoisobutyric acid itself, as well as the corresponding nitrile, with cyanic acid by the method employed above for the ester were unsuccessful.

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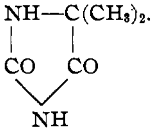
[1] *Ann.*, **290**, 29 (1896).

Calc. for $C_{11}H_{19}O_4N_3$: C, 51.36; H, 7.39; N, 16.34.
Found: C, 51.46; H, 7.59; N, 16.63.

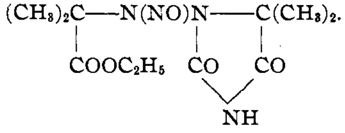
Oxidation Product of the Ethyl Ester of Isobutyric Acid Aminodimethylhydantoin with Bromine.—The oxidation can be carried out either in a dilute alcohol solution or in 50% acetic acid. In one experiment 7 g. of the hydantoin compound were dissolved in 20 cc. of glacial acetic acid and in the course of the oxidation a total of 20 cc. of water added. It was found convenient to aspirate the bromine into the acetic acid until it imparted for five minutes a deep yellow color to the solution. The excess of bromine was then discharged by leading in sulfurous acid gas. The acid was next neutralized with ammonia, whereupon an oil separated and a further amount was obtained by shaking out the aqueous layer with ether. This oil decomposes at about 110° *in vacuo* with steady gas evolution and with the sublimation of a beautifully crystallizing white solid, probably acetonylurea,



—The oil, dissolved in absolute alcohol, separates out a white crystalline substance on the addition of sodium alcoholate. For analysis a sample of the oil in ether was dried with potassium carbonate, and the ether removed at 60° *in vacuo.* This oil, which has a specific gravity 1.0524, is probably the ethyl ester of bis-1-isobutyric acid amino-5-dimethylhydantoin. However, the product has so far not been prepared sufficiently pure to furnish a conclusive analysis.

Calc. for $C_{22}H_{36}O_8N_6$: C, 51.56; H, 7.03; N, 16.41.
Found: C, 49.71; H, 8.09; N, 17.98.

Ethyl Ester of Nitroso-1-Isobutyric Acid Amino-5-Dimethylhydantoin,



—The hydantoin ester is dissolved in glacial acetic acid, the solution cooled in ice-water, and one and a half mols of solid sodium nitrite stirred in. After the reaction is complete, the acetic acid is neutralized with ammonia, whereupon the nitroso derivative precipitates. Its solubilities are similar to those of the mother substance. From water it crystallizes in laminae of thin plates of a faint yellow color, which melt undecomposed at 104°. The substance gives the Liebermann reaction.

Calc. for $C_{11}H_{18}O_5N_4$: C, 46.15; H, 6.29; N, 19.58.
Found: C, 46.05; H, 6.44; N, 19.84.

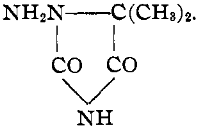
Nitroso-1-isobutyric Acid Amino-5-Dimethylhydantoin.—The nitroso ester described above is warmed for thirty minutes with a slight excess of strong potassium hydroxide solution. On neutralizing with hydrochloric acid under cooling, the nitroso acid separates out. It is soluble in alcohol, acetic ether, ether, and water, crystallizing from the latter solvent in minute rhombic plates, which melt at 165° with decomposition.

Calc. for $C_9H_{14}O_5N_4$: C, 41.86; H, 5.43; N, 21.71.
Found: C, 41.80; H, 5.72; N, 21.73.

1-Isobutyric Acid Amino-5-Dimethylhydantoin. — The hydantoin ester is readily saponified by treatment with a slight excess of strong potassium hydroxide solution for fifteen minutes at water-bath temperature. On acidifying with hydrochloric acid, the hydantoin acid crystallizes out. It is readily soluble in alcohol, acetic ether and hot water, moderately soluble in chloroform and ether, and difficultly soluble in benzene. Purified from water, the acid is obtained in long, slender, prismatic plates, melting at 192.5° undecomposed. Above 200° it decomposes with gas evolution, and on cooling remains viscous.

Calc. for $C_9H_{15}O_4N_3$: C, 47.16; H, 6.55; N, 18.34.
Found: C, 46.96; H, 6.62; N, 18.55.

1-Amino-5-Dimethylhydantoin,



—6 g. of the hydantoin ester are put into 30 cc. of 50% sulfuric acid, and the mixture heated in an oil bath at 110° for four hours after complete solution has been effected. The reaction is attended with a vigorous gas evolution. For the isolation of the aminohydantoin, the sulfuric acid is carefully poured into an excess of ammonium hydroxide with cooling, the solution evaporated to dryness *in vacuo*, and the residue extracted with acetic ether. This hydrazine is readily soluble in water and the common organic solvents, petrolic ether excepted. Purified by crystallization from benzene and then from acetic ether, it is obtained in long, slender prisms, melting undecomposed at 170°. It readily forms a benzoyl and a benzylidene derivative. The hydrazine reduces bromine water, permanganate and mercuric oxide in the cold and there separates in extremely poor yield a small amount of an oxidation product, the investigation of which will be taken up later. It is to be expected that conditions will be established here for obtaining the oxidation product, which is probably a tetrazene, in satisfactory yield.[1]

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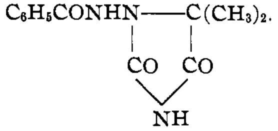
[1] This Journal, 30, 1412 (1908).

Calc. for $C_5H_9O_2N_3$: C, 41.96; H, 6.29; N, 29.37.
Found: C, 41.98; H, 6.38; N, 29.61.

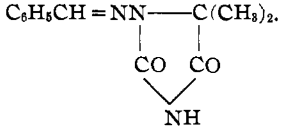
1-Benzoylamino-5-Dimethylhydantoin,



—One gram of the aminohydantoin is boiled with one mol of benzoyl chloride in acetic ether solution for one hour. Reaction takes place readily and one-half of the aminohydantoin separates as the hydrochloride. This salt was not analyzed. After filtration, the acetic ether solution is evaporated to dryness, any benzoic acid removed by extraction with ether, and the residue crystallized from water. Thus purified it melts at 241° to a clear liquid undecomposed.

Calc. for $C_{12}H_{13}O_3N_3$: N, 17.00.
Found: N, 17.02.

1-Benzylideneamino-5-Dimethylhydantoin,



—The benzylidene compound separates in quantitative yield on shaking an aqueous solution of the aminohydantoin with the calculated amount of benzaldehyde. By recrystallization from alcohol it can be obtained in long needles, melting undecomposed at 191–192°. The substance is readily soluble in ether, benzene and chloroform, and almost insoluble in water.

Calc. for $C_{12}H_{13}O_2N_3$: C, 62.34; H, 5.63; N, 18.18.
Found: C, 62.43; H, 5.78; N, 18.45.

The above hydrazone can also be prepared by condensing cyanic acid with benzylidene hydrazinoisobutyric acid[1] as follows: The latter sub-

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[1] *Preparation of Benzylidene Hydrazinoisobutyric Acid.*—20 g. of hydrazine sulfate in 50 cc. of water are converted to the acid salt $(NH_2NH_2)_2.H_2SO_4$ by the addition of 21.2 g. of potassium carbonate. 17.8 g., one mol, of acetone are next added under cooling, and this solution is then treated with a concentrated solution of one mol of sodium acid sulfite. After standing two hours 10 g. of potassium cyanide, one mol, is added to the solution, whereupon a supernatant layer of oil separates. In order to convert the hydrazinoisobutyronitrile, $NH_2NHC(CH_3)_2CN$, to its amide, the mixture is allowed to stand twenty-four hours with twice its volume of concentrated hydrochloric acid, and saponification finally effected by boiling the solution for one hour. The excess of mineral acid is removed by distillation *in vacuo,* the residue taken up with a little water, an excess of sodium acetate added, and the solution treated in the usual way with benzaldehyde. In this way a mixture of benzylidene hydrazinoisobutyric acid and benzalazine is obtained. The method of Thiele and Heuser (*Ann.*, **290,** 16

stance in glacial acetic acid is treated with potassium cyanate by the method described above in the preparation of the ethyl ester of 1-isobutyric acid amino-5-dimethylhydantoin. The reaction mixture is allowed to stand twelve hours, and is then diluted to eight times its volume, whereupon the difficultly soluble 1-benzylidene amino-5-dimethylhydantoin separates. Working with 5 g. of benzylidene hydrazinoisobutyric acid in 50 cc. of glacial acetic acid, 4.6 g. of the condensation product were obtained, and this proved identical with the product described in the foregoing preparation. The benzylidene compound thus obtained for further confirmation of its constitution was submitted to steam distillation in the presence of one mol of sulfuric acid. Benzaldehyde collected in the receiver and 1-amino-5-dimethylhydantoin was isolated from the solution in the distillation flask by the method employed above in the preparation of this substance. All attempts to condense cyanic acid with benzylidene hydrazinoisobutyric acid in water solution failed.

Action of Potassium Cyanate on the Hydrochloride of Ethyl Hydrazinoisobutyrate.—To 2.9 g. of ethyl hydrazinoisobutyrate, prepared according to the method of Thiele and Heuser,[1] was added the calculated amount of hydrochloric acid, and then 1.8 g. of potassium cyanate. After standing overnight, the solution did not react with benzaldehyde, a proof that no aminodimethylhydantoin is formed. Extraction with chloroform yielded a product that proved to be ethyl semicarbazinoisobutyrate,

$$NH_2CONHNHC(CH_3)_2COOC_2H_5.^2$$

As further confirmation, a nitrogen determination was made.

Calc. for $C_7H_{15}O_3N_3$: N, 22.22. Found: N, 22.13.

AUSTIN, TEXAS.

THE VAPOR PRESSURE OF ETHANE AND ETHYLENE AT TEMPERATURES BELOW THEIR NORMAL BOILING POINTS.[3]

BY G. A. BURRELL AND I. W. ROBERTSON.

Received June 3, 1915.

The authors of this report have needed at various times, in working on the condensation of the constituents in natural gas, and in studying the separation of gas mixtures by fractionally distilling them, certain

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(1896)) may be used to remove the benzalazine. Stir the mixture of benzaldehyde compounds with a little dilute ammonia, and after the benzylidene hydrazinoisobutyric acid has completely dissolved, filter from the undissolved benzalazine. Finally extract the last traces of benzalazine from the ammonia solution with ether and then precipitate the benzylidene hydrazino acid by neutralizing with dilute acetic acid. The yield obtained was about 42% of the theoretical (Bailey and Mikeska).

[1] *Loc. cit.*

[2] *Am. Chem. J.*, **28**, 386 (1902).

[3] Published by permission of the Director of the Bureau of Mines.