Octaacetyl-*d*-α,α-galaoctitol.—A mixture of 1.5 g. of *d*-α,α-galaoctitol, 1 g. of fused sodium acetate, and 15 cc. of acetic anhydride was heated gently and, following a vigorous exothermic reaction, refluxed for fifteen minutes. The reaction mixture was poured upon crushed ice and the octaacetate isolated in a yield of 2.4 g. (70%). It crystallized from 5 parts of 95% alcohol in rectangular elongated plates melting at 141° (corr.) and rotating +40.4° (*c*, 1.2; *l*, 4) in chloroform.

Anal. Calcd. for $C_{24}H_{34}O_{16}$: C, 49.8; H, 5.9; acetyl, 59.5. Found: C, 49.8; H, 6.0; acetyl, 59.6.

***d*-α,α-Galaoctose Benzyl Mercaptal.**—A solution of 1 g. of *d*-α,α-galaoctose monohydrate in 2 cc. of concentrated hydrochloric acid was shaken with 2 cc. of benzyl mercaptan, crystallization of the mercaptal occurring in ten minutes. The solid was filtered off, washed repeatedly with alcohol to remove excess mercaptan and recrystallized from 200 parts of 60% alcohol; yield 1.4 g. (78%). The mercaptal melts at 208–209° (corr.) and rotates +18.5° (*c*, 0.8; *l*, 4) in absolute pyridine.

Anal. Calcd. for $C_{22}H_{30}O_7S_2$: S, 13.6. Found: S, 13.4.

***d*-α,α-Galaoctose Benzyl Mercaptal Heptaacetate.**—One gram of the octose mercaptal was acetylated with pyridine and acetic anhydride in the usual manner. The mercaptal acetate was difficult to crystallize, finally being obtained in needles melting at 88–89° (corr.) and having a rotation of −29.6° (*c*, 0.84; *l*, 4) in chloroform.

Anal. Calcd. for $C_{36}H_{44}O_{14}S_2$: S, 8.4. Found: S, 8.2.

Summary

The configuration of the groups about carbon two of *d*-α,α-galaoctonic acid has been established by the preparation of a levorotating amide and phenylhydrazide; this observation completes the proof of the configuration of Fischer's *d*-α,α-galaoctose. The first five carbon atoms of the octose possess the configuration of the corresponding ones of *l*-galactose. A study of *d*-α,α-galaoctose and of many of its crystalline derivatives shows their properties to be closely similar to those of the corresponding substances of the *l*-galactose series, thus extending the view that the physical and chemical properties of lactonyl aldose compounds are conditioned by the spatial arrangement of carbons one to five, to an aldooctose.

The specific rotation of *d*-α,α-galaoctonic amide has been calculated, using numerical data previously established in studies of the hexonic amides and found to agree with the observed value, showing that optical superposition holds closely for such amides.

Comparison of the observed rotations of several pairs of *d*-α,α-galaoctose derivatives with those calculated by the iso-rotation rules shows good agreement.

Attention has been called to the value of preparation of the sugar alcohol acetates as an aid in determining the question of the optical activity or inactivity of sugar alcohols.

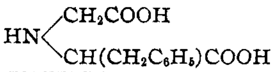
WASHINGTON, D. C. RECEIVED FEBRUARY 18, 1938

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF MOUNT HOLYOKE COLLEGE]

Salts and Hydantoin Derivatives of β-Phenylalanine-N-acetic Acid

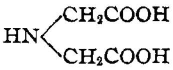
BY DOROTHY A. HAHN AND MARGARET M. ENDICOTT

The preparation of β-phenylalanine-N-acetic acid already has been reported[1] but a modification of the method originally used in the hydrolysis of N-3-methyl-5-benzylhydantoin-N-1-acetic acid[2] has increased the yield to approximately 90% of the theoretical so that a detailed study of its derivatives is possible. Attention has been called to the close analogy which exists between this substance and iminodiacetic acid.[3]



$$\mathrm{HN}\left\langle\begin{array}{l}\mathrm{CH_2COOH}\\ \mathrm{CH(CH_2C_6H_5)COOH}\end{array}\right.$$

and



$$\mathrm{HN}\left\langle\begin{array}{l}\mathrm{CH_2COOH}\\ \mathrm{CH_2COOH}\end{array}\right.$$

It now appears that differences in the behavior of the two compounds are due mainly to differences in the symmetry of their respective molecules. And in this connection it should perhaps be noted that in the case of β-phenylalanine-N-acetic acid, it is not always possible to assign definite structural formulas to such of its derivatives as result from the replacement of only one of the two hydrogen atoms present in the carboxyl groups.

Both acids react with hydrochloric acid to form the corresponding salts. In the case of iminodiacetic acid the product is apparently a stable compound and can be prepared by dissolving the acid in dilute aqueous hydrochloric acid and then adding concentrated acid to precipitate it[3d] (p. 291). This method cannot be applied in the

---

[1] Hahn and Litzinger, THIS JOURNAL, **54**, 4665 (1932).

[2] Litzinger, *ibid.*, **56**, 675 (1934).

[3] (a) Heintz, *Ann.*, **122**, 276 and **124**, 297 (1862); (b) Eschweiler, *ibid.*, **278**, 231 (1894); (c) Johnson and McCollum, *Am. Chem. J.*, **35**, 65 (1906); (d) Jongkees, *Rec. trav. chim.*, **27**, 287–326 (1908); (e) Bailey and Read, THIS JOURNAL, **36**, 1759 (1914); (f) Bailey and Snyder, *ibid.*, **37**, 938 (1915); (g) Treibs and Dinelli, *Ann.*, **517**, 170 (1935).

case of β-phenylalanine-N-acetic acid. The latter, however, dissolves in boiling concentrated hydrochloric acid from which it separates on cooling in crystalline condition. But the product is hydrolyzed even on standing in cold aqueous solutions and when the dry salt is treated with boiling water it first dissolves and then almost immediately is transformed into the free acid which separates as a precipitate.[4] In this respect it resembles the hydrochloride of phenyl iminodiacetic acid, $HCl{\cdot}NH(CH_2COOH)CH(C_6H_5)$-$COOH$, which has been observed to undergo hydrolysis on standing in aqueous solutions at room temperatures although in this case the transformation was not described as quantitative, 5.0 g. yielding 2.0 g. of the free acid.[5]

Although like iminodiacetic acid β-phenylalanine-N-acetic acid appears to be monobasic on the basis of titrations with phenolphthalein as indicator, direct electrometric titrations against carbonate-free potassium hydroxide show two equivalence points,[6] thus indicating the formation of a dipotassium salt. The latter has not, however, been prepared in quantity or analyzed. In preparing the monopotassium salt of iminodiacetic acid Jongkees states that two equivalents of potassium hydroxide were required[3d] (p. 293) but only one of either alkali was needed in the case of the corresponding potassium and sodium[7] salts of β-phenylalanine-N-acetic acid. Both compounds are stable in aqueous solution. The mono-ammonium salt of imino-diacetic acid[8] has been described by Heintz and also by Jongkees, neither of whom appears to have experienced any difficulty in recrystallizing it. The corresponding salt of β-phenylalanine-N-acetic acid, on the other hand, is hydrolyzed so readily by water that it cannot be recrystallized unless a small quantity of free ammonia is added to its aqueous solutions. The dry salt behaves like the hydrochloride and when treated with boiling water its solution is quickly followed by a quantitative precipitation of the free acid. Moreover this transformation also provides a good method for preparing the acid in exceptionally pure condition.

A barium salt of imino-diacetic acid has been described by Heintz which contains barium in the proportion of one atom to two moles of the acid. This compound is so extremely soluble in water that in order to effect its precipitation alcohol had to be added to its concentrated aqueous solutions.[9] In the case of β-phenylalanine-N-acetic acid two barium salts have been isolated. One of these corresponds in most of its properties to the compound reported by Heintz; the other is almost insoluble in boiling water and contains barium in the ratio of one atom to one mole of the acid.[10] The latter readily may be transformed into the former and *vice versa*.

To continue with this comparison, imino-diacetic acid has been observed to yield a hydantoin which contains an acetic acid residue in the N-1-position. This hydantoin has been obtained in the form of the free acid and also in the form of the corresponding methyl and ethyl esters under a variety of different conditions.[11] Its configuration has been established not only as a consequence of these syntheses, but also because the other two acetic acid derivatives of hydantoin which are theoretically possible have been prepared and their structure definitely determined.[12] In the case of β-phenylalanine-N-acetic acid, the dipotassium salt of the corresponding acyclic ureide was obtained when its monopotassium salt was dissolved in water and the solution treated with one equivalent of potassium cyanate.

---

[4] Solutions of the salt in dilute hydrochloric acid do not crystallize and on evaporation to dryness deposit a gum. However, the latter, when repeatedly dissolved in boiling water and evaporated to dryness, is finally transformed into the free acid which is precipitated in almost pure condition and without appreciable loss. This change is *extremely important* since oily mixtures which are formed as by-products in a variety of different types of reactions can be converted into the hydrochloride, by warming with dilute hydrochloric acid, and subsequently into the free organic acid. In this way the loss of considerable quantities of valuable material can be avoided.

[5] Stadnikoff, *Ber.*, **41**, 4365 (1908).

[6] Litzinger and Pickett, THIS JOURNAL, **56**, 124 (1934).

[7] The monosodium salt of imino-diacetic acid was prepared by H. J. Backer and its conductivity measured. Results seemed to indicate that it behaves like the salt of a monobasic acid. *Chem. Weekblad* **12**, 943–946 (1915); or *Chem. Zentr.*, **86**, II, 1179 (1915).

[8] Heintz, *Ann.*, **124**, 302 (1862); ref. 3d, p. 293.

[9] Heintz, *Ann.*, **124**, 303 (1862).

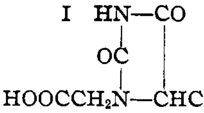
[10] The fact that Heintz was unable to obtain a barium salt of the latter type was probably due to his having removed any excess of barium by passing carbon dioxide into the reaction mixture until it was no longer alkaline. Under these conditions the insoluble barium salt of β-phenylalanine-N-acetic acid is transformed into the soluble compound. Jongkees, however, regarded the results of Heintz's experiment as affording additional evidence in support of his theory that, due to the formation of an "inner salt," only one of the two carboxyl hydrogen atoms present in imino-diacetic acid could be replaced by metals[3d] (pp. 290 and 293). This appeared the more probable since Heintz had succeeded in obtaining two hydrated salts of $NON(CH_2COOH)_2$ in both of which barium was present in the ratio of one atom to one mole of the acid [Heintz, *Ann.*, **138**, 308–311 (1866)].

[11] Jongkees,[3d] pp. 320–326; Bailey and Snyder, THIS JOURNAL, **37**, 940 and also 945–946 (1915); Renfrew and Johnson, *ibid.*, **51**, 1787 (1929).

[12] Compare Johnson and Renfrew, *ibid.*, **47**, 240 (1925), for bibliography covering this work.

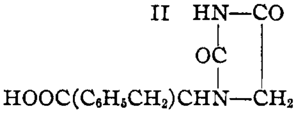
The product $NH_2CON(CH_2COOK)CH(CH_2C_6H_5)COOK$,[13] which was isolated in pure crystalline condition, when dissolved in water and treated with dilute hydrochloric acid, was converted quantitatively into 5-benzylhydantoin-N-1-acetic acid

I



The corresponding acyclic dibasic ureidic acid was not isolated and there is reason to believe that ring closure with the elimination of one molecule of water takes place immediately even at ordinary temperatures following the addition of the mineral acid. The fact that under the conditions of the experiment it takes place exclusively in one sense would seem to indicate that the velocity of this reaction is greater in the case of one of the two carboxyl groups than of the other. This assumption is supported in part by the fact that an isomeric hydantoin acid[14] has

II



been obtained in excellent yields under conditions which preclude ring closure of the type which is now being considered (I).

5-Benzylhydantoin-N-1-acetic acid (I), like hydantoin-N-1-acetic acid[3d] (p. 325), separates from its aqueous solutions with one molecule of water of crystallization. Its configuration has been established definitely by its transformation into N-3-methyl-5-benzylhydantoin-N-1-acetic acid,[2] the latter having been synthesized in such a way as to admit of no question in regard to its structure. It may be added that the sodium salt as well as the methyl and ethyl esters of 5-benzylhydantoin-N-1 acetic acid have also been prepared for purposes of comparison and for reference in later work.

Experimental

The synthesis of the imino acid has been expedited in two ways. Starting with N-3-methyl-5-benzalhydantoin substitution in the N-1-position was carried out in the usual manner[2] (pp. 673–4). The product, ethyl N-3-methyl-5 benzalhydantoin-N-1-acetate, was not isolated, however, in crystalline condition. Instead the crude reaction product was first freed from traces of N-3-methyl-5-benzalhydantoin by passing dry hydrogen chloride into the cooled alcohol solution for a few minutes. After removing the precipitate and concentrating the filtrate to small volume, water was added and the ester extracted with ether. The oily residue remaining after the ether had been evaporated was finally treated with hydrogen iodide and red phosphorus, after which the transformation of the ester into N-3-methyl-5-benzylhydantoin-N-1-acetic acid[2] was carried out in the usual way.

The conversion of this crystalline product into the imino acid has been described as analogous[1] to the conversion of N-3-methyl-5-*p*-hydroxybenzylhydantoin-N-1-acetic acid into tyrosine-N-acetic acid[1] (p. 4664). This method of procedure has now been simplified by avoiding the use of steam distillation as a means for eliminating the methylamine which is formed as a by-product in the hydrolysis. For example, boiling aqueous solutions of the hydantoin (20 g. in 100 cc.) and barium hydroxide (80 g. of recrystallized $Ba(OH)_2 \cdot 8H_2O$ in 200 cc.)[15] were combined and digested for twenty-four hours over a steam-bath in a flask connected with a return condenser. The heating was then discontinued and 300 cc. of boiling alcohol added, when the mixture was cooled, filtered and the precipitate washed with cold alcohol. The filtrate was concentrated to 100 cc. and treated in the same way, while the filtrate from the second precipitate was evaporated to dryness. The combined solids, which had been freed in this way from methylamine, were suspended in 300 cc. of cold water and treated with a quantity of concentrated sulfuric acid slightly in excess of that calculated on the basis of the barium hydroxide. This was added slowly under mechanical stirring until the evolution of carbon dioxide had ceased. The volume was then increased to 1700 cc.[16] by the addition of boiling water and the solution maintained at a temperature slightly below 100° on a steam-bath overnight, in order to ensure the complete conversion into acid of any of the barium salt which is only slightly soluble in boiling water. The mixture was then titrated alternately against dilute equimolar solutions of barium hydroxide and sulfuric acid until the barium and sulfate ions had been exactly equalized, when the hot solution was filtered and the precipitate first washed and later extracted with boiling water. The main portion of the imino acid, which crystallizes very slowly, separated from the filtrate on standing overnight in exceptionally pure condition, m. p. 225–226° (dec.). Additional quantities which were equally pure[17] were obtained by concentrating the filtrate together with the wash water and extract from the precipitate. The acid is fairly soluble in boiling water (1 g. in 95 cc.) and only

---

[13] The same compound was obtained by dissolving the free acid in an aqueous solution containing two equivalents of potassium cyanate.

[14] The formation of this compound will be described in detail in a later paper dealing with the preparation and transformations of the free monoalkyl esters of β-phenylalanine-N-acetic acid.

[15] This amount of base which is in excess of that actually required for the formation of the barium salts of the imino acid and barium carbonate, was found to improve the percentage yield of the acid, which under these conditions averages above 90% of the theoretical.

[16] This was necessary in order to dissolve completely the free imino acid, but the relatively large volume which was required imposed a definite limitation upon the quantity of hydantoin hydrolyzed at any one time, although 60-g. lots have been handled successfully without diminishing the percentage yields.

[17] Even when the last residues were extracted with boiling alcohol no traces of unhydrolyzed hydantoin were detected.

slightly soluble in cold water (1 g. in 650 cc. at 25°). Its analyses have been reported.[1]

The hydrochloride of β-phenylalanine-N-acetic acid, m. p. 200–201° (dec.), was prepared by dissolving the free imino acid (20 g.) in boiling concentrated hydrochloric acid (100 cc., sp. gr. 1.178). The salt (15 g.) separated slowly from the cooled solution as small transparent irregular prisms. Additional amounts, obtained by concentrating the filtrate, indicated that the transformation was quantitative. The product was exceptionally pure and repeated recrystallizations from the same solvent resulted in no appreciable change in its melting point. The air-dried salt when heated at 110° suffered no loss in weight.

Anal. Calcd. for $C_{11}H_{13}O_4N \cdot HCl$: N, 5.40; Cl, 13.68. Found: N, 5.19, 5.23; Cl, 13.42, 13.35.

The salts of the alkali metals[18] were prepared by dissolving β-phenylalanine-N-acetic acid in a small quantity of aqueous alcohol (50%) containing 1.2 equivalents of the base and then adding absolute alcohol. The **ammonium salt** was obtained in the same way from solutions of the acid in ammonium hydroxide. The **barium salts IV and V** were prepared by adding aqueous solutions of barium chloride and barium hydroxide, respectively, to an aqueous solution of the potassium (or sodium) salt. In the case of IV the salt was separated in the form of compact nodules of fine needles by concentrating the aqueous solution to very small volume, after which it was dissolved in water and precipitated with absolute alcohol. The salts I, II, III, and IV were all recrystallized from water–alcohol mixtures, care being taken to prevent hydrolysis in the case of III by adding a drop or two of ammonia. All tend to form gels when ether is added to alcohol or aqueous alcohol solutions. V was purified by repeated extractions with boiling water. It may be added that a **silver salt,** which was precipitated when an aqueous solution of the sodium salt was treated with silver nitrate, decomposed so rapidly that it could not be analyzed.

The acyclic ureide of β-phenylalanine-N-acetic acid was isolated in the form of its dipotassium salt, $H_2NCON(CH_2COOK)CH(CH_2C_6H_5)COOK$, m. p. 241–242° (dec.), when a cold aqueous solution of the monopotassium salt of the imino acid (5.0 g. in 9 cc.) was treated with an equivalent of potassium cyanate (1.55 g. in 7 cc.). The product was obtained as a clear transparent gum when the solution was evaporated to dryness at room temperature under a rapid current of dry air. On treatment with 40 cc. of boiling absolute alcohol, this gum immediately was transformed into a mass of hard white crystals (6.05 g., m. p. 239–241°, dec.) which were filtered and washed with 10 cc. of cold alcohol. It was purified by recrystallization from water–alcohol mixtures from which it separated with two molecules of water of crystallization.[19] The salt is very unstable and suffers a change in color when heated at 80°. When dissolved in dilute hydrochloric acid, it was converted into 5-benzylhydantoin-N-1-acetic acid.

Anal. Calcd. for $C_{12}H_{12}O_5N_2K_2 \cdot H_2O$: C, 39.98; H, 3.91; K, 21.91. Found: C, 39.52; H, 4.02; K, 21.45.

$HOOCCH_2\overline{NCONHCOCH}CH_2C_6H_5$, **5-Benzylhydantoin-N-1-acetic acid,** m. p. 110–111° (with a rapid evolution of gas at 120°), was prepared most conveniently by adding the free imino acid (10 g.) under mechanical stirring to a cold aqueous solution containing 2.1 equivalents of potassium cyanate (7.6 g. in 30 cc.) in an open beaker surrounded by an ice-bath. Since the solution of the imino acid was accompanied by the separation of a small quantity of a glassy gelatinous substance which was assumed to represent cyanuric acid, the reaction mixture was removed from the bath and the stirring continued for fifteen minutes at room temperature. The beaker was then transferred to a hot-plate and heated until the evolution of gas, resulting from the decomposition of the excess of cyanic acid, had ceased. The clear colorless solution was

TABLE I

	Formula	M. p., °C.	Appearance	Analyses nitrogen, % Calcd.	Found		Metal, % Calcd.	Found	
I	$C_{11}H_{12}O_4NK$	205–208° dec.	Rosets of *very* long soft fine needles	5.36	5.32	5.20	14.97	14.62	14.50
II	$C_{11}H_{12}O_4NNa$	270° dec.	Thin transparent plates (glistening when dry)	5.71	5.66	5.59	9.38	9.07	8.94
III	$C_{11}H_{12}O_4NNH_4$	201–203 dec.	Thin transparent plates (glistening when dry)	11.67	11.55	11.48			
IV	$C_{11}H_{12}O_4NBa/2$	Does not melt at 335°	Thin transparent plates (glistening when dry)	4.82	4.90	5.02	23.62	24.30	24.32
V	$C_{11}H_{11}O_4NBa$	Does not melt at 335°	Minute hard granules	4.00	3.85	3.89	39.16	39.16	39.19

I v. s. H_2O; 1.0 g. s. in 650 cc. cold or 150 cc. b. EtOH; insol. Et_2O. II much more soluble than I. III v. s. in cold H_2O but is partially hydrolyzed, hydrolysis complete when the dry salt is treated with b. H_2O; sl. s. in b. 95% EtOH. IV v. s. H_2O, sl. s. b. 95% EtOH; aq. soln. + $Ba(OH)_2$ gives V; forms "snake" on Pt. V ins. b. H_2O; dissolves slowly in H_2O + CO_2 and in aq. AcOH to give IV; carbonized on Pt. All yields quantitative.

---

[18] I and II in the following table.

[19] The analyzed specimen was dried in a high vacuum at room temperature. Another specimen which was analyzed after standing in a desiccator over calcium chloride for several days was found to contain approximately two molecules of water of crystallization. Other analyses showed that the second molecule of water was given off slowly and incompletely at ordinary temperatures. The same salt was formed in practically quantitative amounts when the free imino acid was dissolved in aqueous potassium cyanate (2 equivalents), but could not be separated readily due to the presence of free cyanic acid.

cooled, filtered if necessary and acidified immediately with hydrochloric acid. The product which separated at once as a crystalline precipitate was exceptionally pure (9.0 g., m. p. 110–111°). This was filtered, washed with cold water and dried in the air. Additional small quantities were obtained by concentrating the filtrate, the yield averaging more than 90% of the theoretical. The acid was recrystallized several times from boiling water without appreciable change in its melting point. It separates from its hot aqueous solutions on cooling as small transparent prisms or diamond shaped plates but when cold aqueous solutions are allowed to evaporate slowly at room temperature large transparent rhombohedra are formed with diamond-shaped bases 8 × 8 mm. and sides 3 × 8 mm. The acid crystallizes with one molecule of water only part of which it loses to form a glass at 110°. When heated at higher temperatures it suffers partial decomposition. Although the formation of a glass was finally prevented and the water completely removed by successive additions of anhydrous ether to the powdered hydrate heated at 80°, no attempt was made to analyze the anhydrous acid, which melts at 138° to a clear oil.

Anal. Calcd. for $C_{12}H_{12}O_4N_2 \cdot H_2O$: C, 54.12; H, 5.30; N, 10.53; H_2O, 6.77. Found: C, 54.35, 54.37; H, 5.11, 5.13; N, 10.58; H_2O, 6.90, 7.08.

The acid is very soluble in boiling water (1 g. in 5 cc.) but tends to separate as an oil if the solutions are too concentrated; it is only slightly soluble in cold water (1 g. in 250 cc. at 20°) and ether. While dissolving readily in cold alcohol, it is partially esterified even at room temperatures. It is very soluble in chloroform. In order to complete its identification, its sodium salt as well as the corresponding methyl and ethyl esters were prepared and analyzed.

Sodium 5-benzylhydantoin-N-1-acetate, m. p. 303–304° (dec.), was prepared by adding aqueous sodium hydroxide (1.7 g. in 20 cc.) to an alcohol solution of the acid (10 g. in 100 cc.). Since the solution remained clear after standing at room temperature overnight, anhydrous ether (100 cc.) was added. The precipitate of large thin glistening white plates which separated immediately was filtered, washed with 30 cc. of alcohol–ether (1:2) and dried in the air (6.1 g., m. p. 303–304°). Additional amounts recovered from the filtrate indicated that the transformation was practically quantitative. The salt showed no appreciable change in melting point when dissolved in water and reprecipitated by the addition of alcohol and ether. Dried in the air it suffered no loss in weight when heated at 110°.

Anal. Calcd. for $C_{12}H_{11}O_4N_2Na$: Na, 8.51. Found: Na, 8.24, 8.15.

The salt passed quantitatively into the corresponding acid when its aqueous solution was acidified with hydrochloric acid.

Methyl 5-benzylhydantoin-N-1-acetate, m. p. 119–120°, was prepared by passing dry hydrogen chloride into a solution of the acid in absolute methyl alcohol (5 g. in 50 cc.). The solution was heated in an open beaker over a steam-bath until the odor of hydrogen chloride had almost completely disappeared, small amounts of alcohol being added from time to time in order to maintain a volume of 30 cc. The addition of water (5 cc.) to the cooled solution caused the immediate precipitation of hard transparent prisms or diamond-shaped plates. The product was extracted with small quantities of boiling water in order to remove any possible traces of acid that might be adhering to it and recrystallized several times from alcohol–water mixtures. After being dried in the air it suffered no loss in weight when heated at 80°.

Anal. Calcd. for $C_{13}H_{14}O_4N_2$: C, 59.51; H, 5.38; N, 10.69. Found: C, 59.67, 59.57; H, 5.08, 5.00; N, 10.73.

The ester is very soluble in cold methyl alcohol and in chloroform but only slightly soluble in ether. It also dissolves in boiling water, from which it separates unchanged on cooling. When heated with aqueous hydrochloric acid it is converted into the corresponding acid.

Ethyl 5-benzylhydantoin-N-1-acetate, m. p. 111–112°, was prepared by dissolving the acid in absolute alcohol and then proceeding in the manner described above. It was purified by recrystallization from alcohol–water mixtures from which it separates in small transparent prisms or diamond-shaped plates. Although it resembles the corresponding acid in its crystalline form and melting point,[20] it is readily distinguished from it by its relatively greater solubility in cold alcohol and its marked insolubility in cold water as well as by the fact that a mixture of the two compounds melts at 94–96°. Dried in the air and heated at 80° it suffers no change.

Anal. Calcd. for $C_{14}H_{16}O_4N_2$: C, 60.84; H, 5.84; N, 10.24. Found: C, 60.88, 60.76; H, 5.71, 5.80; N, 10.15.

The ester is slightly soluble in boiling water but, unlike the corresponding methyl ester, is partially hydrolyzed in solution. Heated with aqueous hydrochloric acid it passes quantitatively into the corresponding acid.

The molecular configuration of the acid was determined definitely by converting it into N-3-methyl-5-benzylhydantoin-N-1-acetic acid.[2] The best method consisted in adding the sodium salt of the acid (3.85 g., m. p. 303–304°) to a solution of sodium alcoholate (0.40 g. sodium in 40 cc. absolute alcohol). The salt dissolved to form a clear colorless solution which when warmed on a steam-bath in a flask connected with a return condenser almost instantly became filled with a semi-solid mass of crystals. A slight excess over the calculated quantity of methyl iodide was then added to the reaction mixture and the heating continued for fifteen minutes, at the end of which time the solution had again become perfectly clear. Since no solid separated on cooling, absolute ether (175 cc.) was added. This caused the immediate precipitation of a fine white powder[21] (4.0 g.) which was filtered and washed with an alcohol–ether mixture. The product was quite soluble in boiling absolute alcohol from which it separated on cooling in glistening thin white plates, m. p. 275–276°, and was found to be identical with a specimen of sodium N-3-methyl-5-benzylhydantoin-N-1-acetate which had been prepared synthetically[2] (p. 676). Additional quantities of the same salt recovered from the filtrate showed that the reaction was practically quantitative.

The salt, dissolved in water and treated with hydrochloric acid, was transformed quantitatively into an acid m. p. 150–151°, which separated as a crystalline precipi-

---

(20) Except for the fact that it contains no water of crystallization and therefore melts without effervescence to a clear liquid.

(21) This was contaminated by traces of sodium iodide.

tate and which on the basis of its crystalline structure, solubility in different solvents, as well as of a mixed melting point determination, was found to be identical with a specimen of N-3-methyl-5-benzylhydantoin-N-1-acetic acid which had been prepared synthetically.[2]

Summary

β-Phenylalanine-N-acetic acid belongs to the class of imino-dibasic acids and resembles iminodiacetic acid in many respects although some of its derivatives are much less stable. It is the only acid of this class which has as yet been described as forming an acyclic ureide under the direct action of potassium cyanate.

Although, on the basis of theoretical considerations, ring closure with the elimination of one molecule of water should result in the formation of two isomeric hydantoins characterized by different acid groups in the N-1-position, only one such compound was obtained when the dipotassium salt of the acyclic ureide was treated with hydrochloric acid. The formation of the isomer under entirely different conditions will be described in a later paper.

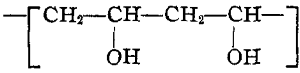
South Hadley, Mass. Received January 11, 1938

[Contribution from the Chemical Laboratory of the University of Illinois]

The Structure of Vinyl Polymers. II.[1] Polyvinyl Alcohol

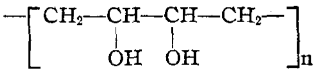
By C. S. Marvel and C. E. Denoon, Jr.[2]

The peroxide catalyzed polymerization of vinyl compounds produces linear polymers of considerable technical importance but the exact structures of these polymers have not received much attention. Staudinger[3] prepared polyvinyl alcohol from polyvinyl acetate and ascribed to these polymers the 1,3-glycol (and ester) structure (I). In a later article[4] the statement was made that oxalic and succinic acids were oxidation products of polyvinyl alcohol. The formation of oxalic acid from the polymeric 1,3-glycol (I) would be expected, but it is difficult to see how succinic acid could be formed from this structure. On the other hand, succinic acid would be the expected oxidation product of the polymeric 1,2-glycol structure (II) which is a second possible structure for polyvinyl alcohol. Staudinger, Frey and Stark[4] have obtained some acetaldehyde by heating polyvinyl alcohol to 200°. Herrmann and Haehnel[5] have reported iodoform as a product of the action of sodium hypoiodite on polyvinyl alcohol. Both reactions indicate that the 1,3-glycol structure (I) is the correct formulation for the polymer. Thus, the evidence now available in the literature may be said to indicate that polyvinyl alcohol contains both 1,2- and 1,3-glycol units.



$$-\left[\mathrm{CH_2-\underset{OH}{CH}-CH_2-\underset{OH}{CH}-}\right]_n$$

I



$$-\left[\mathrm{CH_2-\underset{OH}{CH}-\underset{OH}{CH}-CH_2-}\right]_n$$

II

We have tried to repeat the nitric acid oxidation of polyvinyl alcohol to yield oxalic and succinic acids. However, oxalic acid was the only product which we obtained. It is interesting to note that anhydrous oxalic acid melts at 189° and in our work was first mistaken for succinic acid (m. p. 188°). Since no experimental details of the earlier isolation of succinic acid[4] are recorded it is possible that the earlier investigators made the same error which we first made.

Periodic acid has been shown[6] to be a specific oxidizing agent for 1,2-glycols. Hence if there are any 1,2-glycol units in polyvinyl alcohol it should be possible to detect them with this reagent.[7] Accordingly a 0.2 *M* (based on $(-\mathrm{CH_2{-}CHOH}-)_2$ as the unit) solution of polyvinyl alcohol was treated with a standardized solution of periodic acid at 0° and samples were withdrawn and titrated from time to time to determine whether any oxidation had occurred. No evidence of any oxidation was found although the experiment was continued for thirteen hours. As

---

(1) For the first communication on this topic see Marvel and Levesque, This Journal, **60**, 280 (1938).

(2) Du Pont Fellow in Chemistry.

(3) Staudinger, *Ber.*, **59**, 3019 (1926).

(4) Staudinger, Frey and Stark, *ibid.*, **60**, 1782 (1927).

(5) Herrmann and Haehnel, *ibid.*, **60**, 1658 (1927).

(6) (a) Malaprade, *Compt. rend.*, **186**, 382 (1928); *Bull. soc. chim.*, [5] **1**, 833 (1934); (b) Fleury and Fatome, *J. pharm. chim.*, [8] **21**, 247 (1935); (c) Karrer and Hirohata, *Helv. Chim. Acta*, **16**, 959 (1933); (d) Jackson and Hudson, This Journal, **59**, 2049 (1937).

(7) The use of periodic acid for this purpose was suggested to the authors by Dr. G. J. Berchet.