which showed no melting point depression with an authentic sample.

Acetolysis of 2-(phenylethynyl)tetrahydropyran (I). A tightly stoppered flask containing 5.6 g. (0.30 mole) of I, 0.5 g. of mercuric oxide, 0.2 ml. of boron trifluoride etherate, and 18 g. of glacial acetic acid was heated on a steam bath for 1 hr. The mixture was poured into cold water which was then extracted with ether. The ether solution was washed with aqueous sodium bicarbonate, dried, and fractionally distilled at 107–148° (1 mm.). Separation was unsatisfactory, but refractive indices varied from 1.5285 to 1.5380 at 20°. Decomposition seemed to occur and the odor of acetic acid or anhydride was noticeable in many fractions.

The 2,4-dinitrophenylhydrazone of VII was obtained from one of the fractions.

CHICAGO 14, ILL.

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, DEPAUL UNIVERSITY]

Glucosylation of Acetylenes[1]

ROBERT ZELINSKI[2] AND ROBERT E. MEYER

Received December 3, 1957

The first example of a glucosylated acetylene has been prepared by reaction of tetraacetyl-α-D-glucopyranosyl bromide with phenylethynylmagnesium bromide. The hydrate (II) of this compound, 1-phenyl-2-(tetraacetyl-β-D-glucopyranosyl)-ethyne (I), was catalytically reduced to 1-phenyl-2-(tetraacetyl-β-D-glucopyranosyl)ethane (IV) which was also prepared by the analogous glucosylation of 2-phenylethylmagnesium bromide. Glucosylation of sodium acetylide gave a small yield of a crystalline carbohydrate derivative of undetermined structure.

The glucosylation of hydrocarbons with a carbohydrate moiety in which the pyranose ring is preserved has been accomplished by using glycosyl halides in two familiar organic reactions. Thus the Friedel-Crafts reaction has led to the glycosylation of aromatic hydrocarbons. The second and more general way is the coupling of organometallic compounds with α-halo ethers, as extended to include glycosyl halides, a procedure of obviously greater scope. Both approaches were originated by Hurd and Bonner[3] and extended by them in work which has been largely reviewed by Bonner.[4] Since then the glycosylation of organometallics has been applied to a variety of carbohydrates[5] and Grignard reagents[5–9] as well as to organocadmium[10] and organoalkali[11] compounds. It was our purpose to extend the scope of this synthesis still further by employing organometal derivatives of 1-alkynes.

The only report in the literature concerning attempted glycosylation of acetylenes is that of unsuccessful efforts[5] to couple tetraacetyl-α-D-glucopyranosyl bromide with ethynebis(magnesium bromide) and with sodium or lithium acetylide. Since the application of common reactions of acetylenes to glycosylated acetylenes would obviously provide a starting point for the preparation of many novel carbohydrates and derivatives, the problem of glycosylating acetylenes was attempted again. However, in view of the reported lack of success with metal derivatives of acetylene itself,[5] phenylacetylene was selected first.

The procedures developed by Hurd and Bonner were applied to the coupling of one mole of tetraacetyl-α-D-glucopyranosyl bromide with twelve of phenylethynylmagnesium bromide. From the ether phase of the usual hydrolysis mixture methylbisphenylethynylcarbinol was recovered in good yield. Acetylation of the dehydrated aqueous phase and crystallization of the crude material from anhydrous alcohol or hydrocarbon solvent gave a levorotatory, crystalline compound, m.p. 134–135°, which we describe as anhydrous 1-phenyl-2-(tetraacetyl-β-D-glucopyranosyl)ethyne (I). Evaporation of the mother liquor left a dextrorotatory sirup which could not be crystallized.

Recrystallization of I or the crude product from wet isopropyl or 95% ethyl alcohol gave a different crystalline species (II), m.p. 125–126°. The specific rotations of I and II were identical, the two compounds were interconvertible by crystallization from suitable solvents such as benzene and even ethanol, and II was readily dried to yield I. All the analytical evidence supports designation of

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(1) This work was made possible by grant from the Research Corp.

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(3) C. D. Hurd and W. A. Bonner, *J. Am. Chem. Soc.*, **67**, 1664, 1972 (1945).

(4) W. A. Bonner, *Friedel-Crafts and Grignard Processes, Advances in Carbohydrate Chemistry*, Academic Press, Inc., New York City, 1951, Vol. 6, pages 251–289.

(5) C. D. Hurd and R. P. Holysz, *J. Am. Chem. Soc.*, **72**, 1732 (1950).

(6) Yu. A. Zhdanov, L. I. Shcherbakova, and T. N. Egorova, *Doklady Akad. Nauk S.S.S.R.*, **83**, 403 (1952); *Chem. Abstr.*, **47**, 2710 (1953).

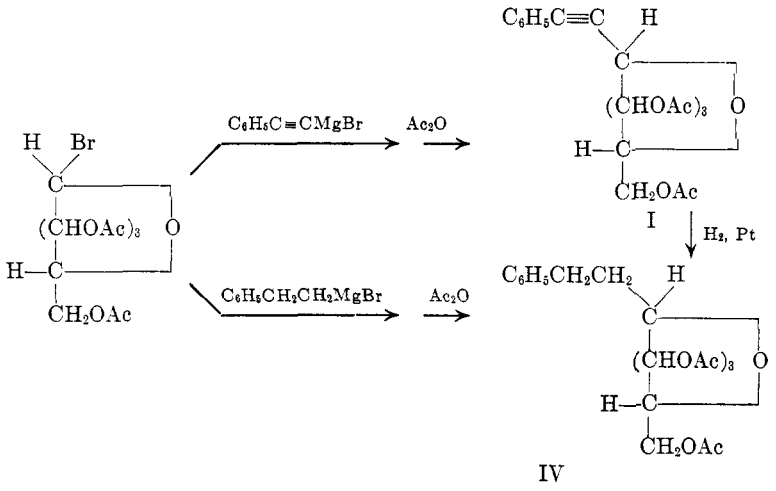
(7) Yu. A. Zhdanov and L. I. Shcherbakova, *Doklady Akad. Nauk S. S. S. R.*, **90**, 185 (1953); *Chem. Abstr.*, **48**, 5114 (1954).

(8) Yu. A. Zhdanov, L. I. Shcherbakova, and R. V. Golovnya, *Doklady Akad. Nauk S.S.S.R.*, **107**, 259 (1956); *Chem. Abstr.*, **50**, 15476 (1956).

(9) Yu. A. Zhdanov and G. F. Drofeenko, *Doklady Akad. Nauk S.S.S.R.*, **112**, 433 (1957).

(10) C. D. Hurd and R. P. Holysz, *J. Am. Chem. Soc.*, **72**, 2005 (1950).

(11) C. D. Hurd and R. P. Holysz, *J. Am. Chem. Soc.*, **72**, 1735 (1950).



II as $(C_{22}H_{24}O_9)_4 \cdot H_2O$, a stable hydrate of 1-phenyl-2-(tetraacetyl-β-D-glucopyranosyl) ethyne (I).

Deacetylation of I or of II was readily accomplished to yield 1-phenyl-2-(β-D-glucopyranosyl) ethyne. When this was recrystallized from 95% ethanol, it was collected as a hydrate or alcoholate, m.p. 122–122.5°, but vacuum drying left an anhydrous form (III), m.p. 142–143°. Both forms had very similar levorotation.

Deacetylation of the levorotatory sirup left by evaporation of the mother liquor from cystallization of I or II gave a non-crystallizable, dextrorotatory glass which undoubtedly contained the α-form of III.

Hydrogenation of 1-phenyl-2-(tetraacetyl-β-D-glucopyranosyl)ethyne hydrate (II) over platinum oxide formed 1-phenyl-2-(tetraacetyl-β-D-glucopyranosyl)ethane (IV) in almost quantitative yield. This was identical to the product obtained by reaction of the glucosyl bromide with 2-phenylethylmagnesium bromide and subsequent acetylation. By the usual deacetylation procedure it gave glassy 1-phenyl-2-(β-D-glucopyranosyl)ethane (V).

The glucosylated phenylethynes and phenylethanes described above have been designated alpha or beta according to their signs of rotation, alpha being the more dextrorotatory form in the D series.[12] On the basis of Bonner and Hurd's[13] degradation studies there is no reason to expect racemization or inversion of an asymmetric alcoholic carbon or change in ring size during glucosylation of Grignard reagents. Periodate oxidations[5,13,14] of glycosylated benzenes prepared in this manner also support retention of the pyranose ring. It may also be noted that the products obtained from either the alpha or beta glucosyl chloride are substantially identical.[5] Only in glucosylation of phenyllithium has evidence of inversion at an alcoholic carbon been found.[11]

With this demonstration that the acetylenic linkage itself was no barrier to glycosylation, experiments to glucosylate acetylene were conducted. Hurd and Holysz had obtained only tars from boiling acetobromoglucose with a suspension of sodium or lithium acetylide in toluene. By carrying out the coupling under milder conditions we have with difficulty obtained very low yields of a crystalline, strongly levorotatory acetate VI and a much less levorotatory sirup. The composition of the crystalline compound VI closely agreed with that calculated for tetraacetyl-β-D-glucopyranosylethyne (VII). However, catalytic reduction of VI over platinum oxide gave a dextrorotatory sirup which was not tetraacetyl-β-D-glucopyranosylethane (VIII). The latter was separately prepared from the glucosyl bromide and ethylmagnesium bromide and was obtained as a crystalline, levorotatory compound accompanied by a dextrorotatory sirup containing the anomer. It is clear, therefore, that the levorotatory solid VI was not tetraacetyl-β-D-glucopyranosylethyne (VII).

The structure of VI is unknown but it is probably a carbohydrate moiety containing an ethynyl group. It is possible that it differs from the expected ethyne VII only by inversion of one or more alcoholic carbons as has been suggested for an acetate resulting from glucosylation of phenyllithium.[11] However, other courses of reaction can be postulated such as the formation of 1,2-alkylidenetriacetylglucose from reaction of certain organocadmiums.[10] In any event, the physical constants of VI did not agree with those of any compound which could be formed by base-catalyzed elimination from the glucosyl bromide.

Attempts to couple tetraacetyl-α-D-glucopyranosyl bromide with ethynebis(magnesium bromide) in ethyl ether were no more successful than earlier work.[5] The usual reaction procedure gave only intractable tars.

(12) C. S. Hudson, *J. Am. Chem. Soc.*, **31**, 66 (1909).
(13) W. A. Bonner and C. D. Hurd, *J. Am. Chem. Soc.*, **73**, 4290 (1951).
(14) W. A. Bonner and J. M. Craig, *J. Am. Chem. Soc.*, **72**, 348 (1950).

EXPERIMENTAL[15]

1-Phenyl-2-(tetraacetyl-β-D-glucopyranosyl)ethyne (I). A solution of 1.0 mole of phenylethynylmagnesium bromide was prepared by 30-min. addition of 105 g. (1.08 mole) of phenylacetylene in 150 ml. of anhydrous ether to isopropylmagnesium bromide. The latter was made from 33 g. (1.08 mole) of isopropyl bromide and 25.5 g. (1.05 g.-atom) of magnesium turnings in 350 ml. of anhydrous ether. After the phenylethynylmagnesium bromide solution was boiled for 30 min., heating was discontinued and 37 g. (0.09 mole) of tetraacetyl-α-D-glucopyranosyl bromide[16] in 400 ml. of anhydrous ether was added in one hour. The resultant mixture was heated under reflux with stirring for 6 hr. The ether layer was decanted and the gummy residue was decomposed by the cautious addition of water and a little acetic acid. The ether and aqueous phases were shaken together, filtered, and separated. The ether layer was washed with water, the water layer was washed with ether, and then the ether solutions were combined and the water solutions were combined.

Decolorization of the ether solution with Norit was followed by solvent removal under vacuum at 100°. The 98 g. of residue (89 g. theoretical) was recrystallized from benzene and petroleum ether to give 55 g. (63%) of methylbisphenylethynylcarbinol, m.p. 110–110.5°, identical with the literature value.[17]

The water layer was neutralized to litmus with 10% aqueous sodium hydroxide and evaporated under vacuum at 100°. The residue was stirred and heated at 100° with 200 ml. of acetic anhydride and 10 ml. of pyridine for 3 hr. Acetylation may be very rapid. The mixture was then poured into 200 ml. of ice and water and stirred for two hours before being extracted with ether. This was decolorized with Norit, filtered through infusorial earth and stripped of solvent under vacuum at 100° to leave 19 g. (49%) of a sirupy mixture. Crystallization from 110 ml. of isopropyl alcohol gave 12.7 g. (33%) of 1-phenyl-2-(tetraacetyl-β-D-glycopyranosyl)-ethyne hydrate (II), m.p. 125–126°, $[\alpha]_D^{25}$ −27.4 ($CHCl_3$, *c* 2).

Anal. Calcd. for $(C_{22}H_{24}O_9)_4 \cdot H_2O$: C, 60.47; H, 5.65; loss on drying at 125°, 1.03. Found: C, 60.39, 60.55; H, 5.48, 5.64; loss on drying, 1.00, 1.00.

Benzoic acid was recovered from the alkaline permanganate oxidation of II. When II was melted, cooled, and reheated, the new melting point of 134–135° was observed.

The mother liquor left from crystallization of II was vacuum dried to leave 6.0 g. of amber sirup, $[\alpha]_D^{24}$ +86.7, $[\alpha]_{5461}^{24}$ +101.3 ($CHCl_3$, *c* 2), presumably rich in the alpha anomer of I.

When either the hydrate II or the sirupy mixture was crystallized from anhydrous ethanol or benzene and petroleum ether, the product was anhydrous 1-phenyl-2-(tetraacetyl-β-D-glucopyranosyl)ethyne (I), m.p. 134–135°, $[\alpha]_D^{25}$ −28.7, $[\alpha]_{5461}^{25}$ −33.4 ($CHCl_3$, *c* 2).

Anal. Calcd. for $C_{22}H_{24}O_9$: C, 61.10; H, 5.59. Found: C, 61.01, 61.09; H, 5.64, 5.71.

Crystallization from a solution of I in 95% isopropyl or ethyl alcohol gave the hydrate, II.

1-Phenyl-2-(β-D-glucopyranosyl)ethyne (III). A 4.0-g. sample of the hydrate II was boiled for 10 min. in 40 ml. of anhydrous methanol containing a small piece of potassium. After standing 40 hr., the solution was deionized by passage down a column of 50 g. of Amberlite IR-100 resin followed by 300 ml. of methanol. The combined methanol solution was stripped of solvent to give 2.4 g. (98%) of a hard glass. Five recrystallizations from 95% ethyl alcohol and ethyl ether gave a crystalline substance, m.p. 122–122.5°, $[\alpha]_D^{25}$ −6.3 (H_2O, *c* 4). After vacuum drying for 3 hr. at 100°, there was obtained anhydrous 1-phenyl-2-(β-D-glucopyranosyl)ethyne (III), m.p. 142–143°, $[\alpha]_D^{25}$ −5.6, $[\alpha]_{5461}^{25}$ −6.9 (H_2O, *c* 2).

Anal. Calcd. for $C_{14}H_{16}O_5$: C, 63.62; H, 6.10. Found: C, 63.42; H, 6.34.

Similar deacetylation of the sirup rich in the α-anomer of I gave a noncrystallizable glass, $[\alpha]_D^{26}$ +34.7, $[\alpha]_{5461}^{26}$ +41.1 (H_2O, *c* 2).

1-Phenyl-2-(tetraacetyl-β-D-glucopyranosyl)ethane (IV). Catalytic reduction of 4.3 g. (0.01 mole) of the glucopyranosylethyne hydrate (II) with 0.1 g. of platinum oxide in 150 ml. of 95% ethanol at 40 p.s.i. and 25° resulted in the theoretical pressure drop. Separation of the catalyst and evaporation of two thirds of the alcohol caused crystallization of 4.2 g. (98%) of 1-phenyl-2-(tetraacetyl-β-D-glucopyranosyl)ethane (IV), m.p. 110.5–111°, $[\alpha]_D^{24}$ −26.4 ($CHCl_3$, *c* 2). A mixture with IV prepared by glucosylation *via* 2-phenylethylmagnesium bromide had a melting point of 111–112°.

Compound IV was also prepared by addition of 16.4 g. (0.04 mole) tetraacetyl-α-D-glucopyranosyl)bromide in 150 ml. of dry ether to the Grignard prepared from 89 g. (0.48 mole) of β-phenylethyl bromide and 11.3 g. (0.47 g. atom) of magnesium in 200 ml. of ether. Hydrolysis, evaporation of the aqueous phase, and heating the dry residue with 300 ml. (2.9 moles) of acetic anhydride and 20 g. of sodium acetate for 8 hr. at 100° gave by the usual procedure 11.6 g. (62%) of a sirupy mixture of anomers. Six recrystallizations from isopropyl alcohol gave 4.1 g. (35%) of IV, m.p. 111–112°, $[\alpha]_D^{27}$ −26.3 ($CHCl_3$, *c* 2).

Anal. Calcd. for $C_{22}H_{28}O_9$: C, 60.53; H, 6.46. Found: C, 60.57; H, 6.29.

Oxidation with permanganate formed benzoic acid.

Concentration in vacuum of the mother liquors left from crystallization of IV gave 7.5 g. of amber sirup, $[\alpha]_D^{25}$ +28.8 ($CHCl_3$, *c* 2) which could not be crystallized.

1-Phenyl-2-(β-D-glucopyranosyl)ethane (V). In exactly the same manner as described for deacetylation of the ethyne II to III, so the deacetylation of IV gave 1.3 g. (53%) of glassy 1-phenyl-2-(β-D-glucopyranosyl)ethane (V), $[\alpha]_D^{23}$ −33.5, $[\alpha]_{5461}^{23}$ −39.6 (H_2O, *c* 2). It could not be crystallized.

Deacetylation of the residue left by evaporation of the mother liquor from crystallization of IV also gave a noncrystallizable, hard glass, $[\alpha]_D^{25}$ +36.2 (H_2O, *c* 2).

Tetraacetyl-α-D-glucopyranosyl bromide and sodium acetylide. Fifteen hundred milliliters of liquid ammonia was saturated with acetylene, 23.5 g. (1.02 g.-atom) of sodium was added slowly with stirring. Then acetylene was passed through the solution as 34.8 g. (0.09 mole) of tetraacetyl-α-D-glucopyranosyl bromide in 500 ml. of dry ether was added with stirring in 1 hr. The mixture was stirred for 8 hr. and allowed to stand for 48 hr. as the ammonia boiled away. Then 500 ml. of benzene was added and followed by stirring with cautious addition of 200 ml. of acetic acid. The whole was taken to dryness by vacuum distillation from a water bath.[18] The residue was boiled and stirred with 200 ml. of acetic anhydride and 30 g. of sodium acetate for 5 hr. before being hydrolyzed in 400 ml. of ice water. This mixture was extracted with ether which was then washed with sodium bicarbonate solution, dried, and stripped of solvent in vacuum at 100°. There was left 12.6 g. (41.6%) of sirup which after three recrystallizations from isopropyl alcohol gave 1.3 g. (4.2%) of a crystalline product (VI), m.p. 183–185.5°, $[\alpha]_D^{25}$ −68.8 ($CHCl_3$, *c* 2).

Anal. Calcd. for $C_{16}H_{20}O_9$: C, 53.94; H, 5.66. Found: C, 54.06; H, 5.77.

(15) Microanalyses by Micro Tech Laboratories, Skokie, Ill.

(16) E. J. Bates, *Polarimetry, Saccharimetry and the Sugars*, United States Printing Office, Washington, D. C., 1942, p. 500.

(17) I. Iositsch, *J. Russ. Phys. Chem.*, **35**, 1273 (1903).

(18) In spite of repeated efforts, none of the expected but unknown by-product, methyl-bisethynylcarbinol, could be isolated. Nor has it been possible to synthesize it by other means.

For the first mother liquor there was obtained 2.7 g. (8.9%) of an amber, non-crystallizable sirup, $[\alpha]_D^{25}$ −1.0 ($CHCl_3$, *c* 2).

Various modifications of the glucosylation procedure were examined in the hopes of improving the yield, but all failed to give VI. These included increasing the mole ratio of sodium acetylide to acetobromoglucose to 18:1 and adding the latter as a solid to the liquid ammonia. Attempts were also made to obtain VI by boiling acetobromoglucose with sodium acetylide in ethyl ether or in benzene.

Catalytic reduction over platinum oxide at 25° and 40 p.s.i. of 0.30 g. of compound VI in 200 ml. of ethanol, followed by filtration and evaporation, gave a sirup $[\alpha]_D^{26}$ +38.2, $[\alpha]_{5461}^{26}$ +47.0 ($CHCl_3$, *c* 1.3.).

Tetraacetyl-β-D-glucopyranosylethane (VIII). By the general procedure described earlier 49 g. (0.12 mole) of tetraacetyl-α-D-glucosyl bromide in 600 ml. of ethyl ether was caused to react with the Grignard reagent prepared from 131 g. (1.2 moles) of ethyl bromide and 30 g. (1.2 g.-atom) of magnesium in 200 ml. of ether. After hydrolysis, distillation of the dried ether phase gave 34 g. (72%) of 3-methyl-3-pentanol, b.p. 121–122°, n_D^{22} 1.4170 (lit. b.p. 123°, n_D^{20} 1.4196).[19] The dry residue from stripping the aqueous phase was acetylated to give 10.5 g. (24%) of sirup which slowly crystallized. Recrystallization from isopropyl ether gave 3.1 g. (7.2%) of tetraacetyl-β-D-glucopyranosylethane (VIII), m.p. 91.5–92.5°, $[\alpha]_D^{25}$ −9.0, $[\alpha]_{5461}^{26}$ −10.5 ($CHCl_3$, *c* 2).

Anal. Calcd. for $C_{16}H_{24}O_9$: C, 53.32; H, 6.71. Found: C, 53.31; H, 6.75.

The mother liquors left from crystallization of VIII were stripped of solvent at 100° in a vacuum to leave 6.1 g. of amber, non-crystallizable sirup, $[\alpha]_D^{26}$ +12.2, $[\alpha]_{5461}^{26}$ +13.7 ($CHCl_3$, *c* 2).

CHICAGO 14, ILL.

(19) R. Henry, *Rec. Trav. Chim.*, 26, 94 (1907).

[CONTRIBUTION FROM THE RESEARCH LABORATORY OF AEROJET-GENERAL CORPORATION]

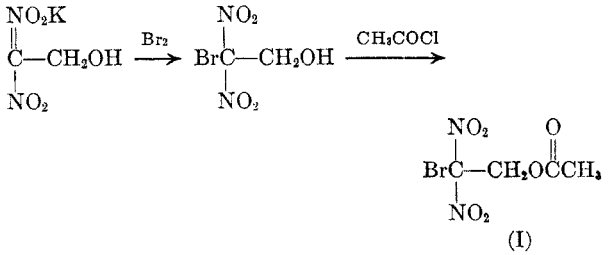
The Dinitroethylation Reaction[1]

MILTON B. FRANKEL

Received October 28, 1957

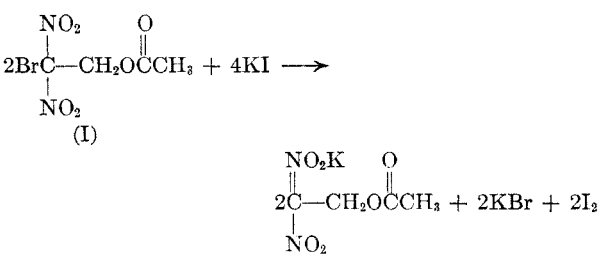
A new reaction has been discovered in the preparation of potassium 2,2,4,4-tetranitrobutyl acetate from 2-bromo-2,2-dinitroethylacetate (I) and potassium iodide. A mechanism is proposed in which 1,1-dinitroethylene is postulated as the reactive intermediate. The generality of this dinitroethylation reaction is indicated by the preparation of potassium 1,1,3,3-tetranitrobutane (VIII) and sodium 1,1-dinitro-2-phthalimidoethane (V) from I and the corresponding salts of 1,1-dinitroethane and phthalimide, respectively. Derivatives of VIII and V are reported.

In continuing the work on aliphatic *gem*-dinitro compounds in this laboratory,[2] attempts were made to prepare potassium 2,2-dinitroethyl acetate. One of the most promising methods for preparing this salt was from the corresponding bromo compound. 2-Bromo-2,2-dinitroethyl acetate (I) was made in an unequivocal manner from potassium 2,2-dinitroethanol.



(I)

It was expected that treatment of 2-bromo-2,2-dinitroethyl acetate with potassium iodide would produce potassium 2,2-dinitroethyl acetate. An analogous reaction was reported by Meisenheimer,[3] who converted 2-bromo-2,2-dinitro-1-ethoxyethane to the corresponding potassium salt by the use of potassium iodide. Klager[4] generalized this procedure and showed that compounds with terminal bromodinitromethyl groups react quantitatively with potassium iodide; the amount of iodine formed corresponds to the theoretical amount of bromine present in the molecule. However, treatment of I with potassium iodide did not give the expected potassium 2,2-dinitroethyl acetate, but a new salt was produced in 64% yield whose analysis was in agreement with potassium 2,2,4,4-tetranitrobutyl acetate (II). Acidification of this salt with dilute sulfuric acid gave a compound whose analysis and neutral equivalent were in agreement with 2,2,4,4-tetranitrobutyl acetate (III). The formation of potassium 2,2,4,4-tetranitrobutyl acetate can be explained as shown in the following equations:



(I)

(1) Presented before the Division of Organic Chemistry at the 133rd meeting of the American Chemical Society, April 13–18, 1958, San Francisco, Calif.

(2) L. Herzog, M. H. Gold, and R. D. Geckler, *J. Am. Chem. Soc.*, **73**, 749 (1951).

(3) J. Meisenheimer, *Ber.*, **36**, 437 (1903).

(4) K. Klager, *Anal. Chem.*, **23**, 534 (1951).