prevented to some extent by protecting one of the amino groups by acetylation.

A solution of 1.16 g. of 4,5-diaminobenzotriazole dihydrochloride and 0.6 cc. of acetic anhydride in 100 cc. of water was treated quickly with a solution of 1 g. of fused sodium acetate in water. The light yellow solution was clarified with charcoal, cooled to 0°, and treated slowly with 4 cc. of 10% sodium nitrite solution. The nearly colorless precipitate (acetate) was dissolved in warm 2% sodium hydroxide solution and precipitated with dilute acid, giving 0.2 g. (25%) of the almost colorless bis-triazolobenzene.

Summary

Methods have been developed for the synthesis of isologs of anthraquinone with either one or two of the benzene rings replaced by a triazole ring. Unfortunately these compounds proved to be so sparingly soluble that only a very limited potentiometric characterization was possible, but the results obtained have some bearing on the problem of the fine structure of the triazole nucleus. This paper includes also a comparison with the views of Fries concerning the bond structure of polynuclear hydrocarbons and quinones.

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[CONTRIBUTION FROM THE DEPARTMENT OF PHYSIOLOGICAL CHEMISTRY, TEACHERS COLLEGE, COLUMBIA UNIVERSITY]

Studies of Crystalline Vitamin B_1.[1] X. Sulfite Cleavage. III. Chemistry of the Basic Product

BY EDWIN R. BUCHMAN, ROBERT R. WILLIAMS AND JOHN C. KERESZTESY

By cleavage of vitamin B_1 with sulfite Williams[2] obtained a basic substance C_6H_9NSO (II), easily isolated as the crystalline hydrochloride in yields up to 97%. The free base is a colorless, rather viscous oil with a characteristic faint basic odor, easily soluble in water, alcohol and chloroform and less readily in ether. It is a mono acid base giving well-defined crystalline derivatives with chloroplatinic, picric and picrolonic acids.

The evidence[3] points to the presence of a free hydroxyl group in the vitamin. Since the oxygen in (II) is evidently derived directly from the vitamin, attempts were made to demonstrate an hydroxyl in (II). With concentrated hydrochloric acid at 150° it was found, as expected, that —OH is replaced by non-ionic chlorine

$$C_6H_9NSO\ (II) \xrightarrow{HCl} C_6H_9NSCl\ (V)$$

(V), obtained in good yield in the form of its crystalline hydrochloride, closely resembles the oxy base (II); the ultraviolet absorption spectra are nearly identical.[4]

When treated with excess *p*-nitrobenzoyl chloride in pyridine, (II) gave a crystalline mononitrobenzoate which still exhibited basic properties. Evidently only the —OH group reacts with acyl chlorides and it may be assumed that the nitrogen in (II) is tertiary in character.

The action on (II) of nitrous acid and of methyl iodide was studied to secure further evidence on this point. With nitrous acid a crystalline product was obtained in good yield, but its analysis and properties showed it to be the nitrate of the original base, $C_6H_9NSO \cdot HNO_3$. With methyl iodide a typical quaternary salt was obtained by allowing the two components to combine slowly at room temperature.

$$C_6H_9NSO\ (II) \xrightarrow{CH_3I} C_6H_9NSO \cdot CH_3I\ (VI)$$

Treatment of the salt (VI) with alkali regenerated no ether-soluble base. In striking contrast to (II) which after heating with 20% alkali at 100° can be recovered unchanged, (VI) under the same conditions was completely destroyed with formation of alkali sulfide. The vitamin itself is readily attacked by hot alkali, also splitting out sulfide.[5] This analogy is consistent with the view that the vitamin is a quaternary salt of (II).[6]

While this investigation was in progress there appeared an article[7] by Windaus, Tschesche and Grewe describing the splitting of the vitamin with nitric acid and the isolation of two well-characterized degradation products, one a sulfur-containing acid $C_5H_5NSO_2$. Oxidation of (II) with nitric acid at 40° gave sulfuric acid and 30% of an acid (VII).

(1) Presented before the Organic Division of the American Chemical Society at the New York Meeting, April, 1935.

(2) R. R. Williams, R. E. Waterman, J. C. Keresztesy and E. R. Buchman, THIS JOURNAL, **57**, 536 (1935).

(3) E. R. Buchman and R. R. Williams, *ibid.*, **57**, 1751 (1935).

(4) A. E. Ruehle, *ibid.*, **57**, 1887 (1935).

(5) A. Windaus, R. Tschesche, H. Ruhkopf, F. Laquer and F. Schultz, *Nachr. Ges. Wiss. Göttingen. Math.-phys. Klasse*, III, 211 (1931).

(6) R. R. Williams, THIS JOURNAL, **57**, 229 (1935).

(7) A. Windaus, R. Tschesche and R. Grewe, *Z. physiol. Chem.*, **228**, 27 (1934).

$$(C_4H_4NS)—C_2H_4OH \xrightarrow{HNO_3} (C_4H_4NS)—COOH$$
(II) (VII)

A comparison of the properties of (VII) with those listed[7] by Windaus for his acid showed that the two substances are identical. The similarity in ultraviolet absorption spectra[4,7] of (II) and (VII) strengthens the view that these substances have a common heterocyclic nucleus C_4H_4NS—.[8] The side chain —C_2H_4OH may be written —$CHOHCH_3$ or —CH_2CH_2OH. The optical inactivity of the vitamin argues against the first formulation. When treated with iodine and alkali (II) gave no iodoform,[9] further indicating that the —OH is in the β position.

Experimental

Basic Cleavage Product C_6H_9NSO (II).—The hydrochloride[2] was available for this work in amounts equivalent to approximately 2 g. of vitamin. It is the salt of a weak[10] base crystallizing in thin bars, readily soluble in water and alcohol, practically insoluble in ether, chloroform and acetone and subliming essentially unchanged at 50° *in vacuo*. Due to its extreme hygroscopicity, great care was necessary in the handling of this substance.

The free base was liberated by making alkaline the aqueous solution of the hydrochloride, shaking out with ether or chloroform and evaporating off the solvent. There was obtained a colorless oil miscible with water but almost insoluble in 20% sodium hydroxide.

An aqueous solution of the hydrochloride gave with phosphotungstic acid an immediate white microcrystalline precipitate. The picrolonate was made by treating an aqueous solution of the hydrochloride with picrolonic acid in methanol. After standing for two days, well-formed yellow crystals had deposited, m. p. 184°[11] (dec.). *Anal.* Calcd. for $C_6H_9NSO \cdot C_{10}H_8N_4O_5$: S, 7.87. Found: S, 8.09. With chloroplatinic acid in alcoholic solution, there was an immediate orange-yellow crystalline precipitate of m. p. 181° (dec.). Under similar conditions with gold chloride, an oil was obtained. The addition of ethereal picric acid to an ether solution of the free base threw down a picrate, m. p. 162–163°, difficultly soluble in ether and in alcohol but moderately soluble in water.

A few crystals of the hydrochloride were subjected to pyrolysis and a pine splinter moistened with hydrochloric acid introduced into the vapors. There was no color formed; the vitamin under the same conditions also gave a negative test. However, the characteristic color which the vitamin develops with diazotized sulfanilic acid was not given by (II). Also, unlike the vitamin, the basic cleavage product was found to be quite stable to hot alkali. A weighed amount (*circa* 20 mg.) of the crystalline hydrochloride was heated at 100° for three-fourths of an hour with 1 cc. of 20% sodium hydroxide. The reaction mixture gave a definitely negative test with nitroprusside[12] solution. A recovery of 90% of the starting material was effected by extraction of the base with ether and conversion into the hydrochloride.

Action of Concentrated Hydrochloric Acid on (II).—26.0 mg. of the hydrochloride of the basic cleavage product was heated in a sealed tube for three hours at 145° with 0.5 cc. of concentrated hydrochloric acid (d. 1.19). The contents of the tube were evaporated to dryness *in vacuo* and taken up in absolute alcohol, yield 27.4 mg. Recrystallization was effected by adding dry ether to the alcoholic solution. After standing overnight 14.5 mg. of cube-like crystals had formed. *Anal.* Calcd. for $C_6H_8NSCl \cdot HCl$: Cl, 35.81; Cl^-, 17.91; N, 7.07; S, 16.19. Found: Cl, 35.47; Cl^-, 18.29; N (Dumas), 7.06; S, 16.36. The substance is much like the hydrochloride of (II) in its solubilities, but it is decidedly less hygroscopic. Also it is noticeably more volatile. *Circa* 10 mg. was dried for analysis at room temperature in a phosphorus pentoxide desiccator connected to a water pump and after twenty-four hours it was found that the entire sample had been volatilized. The free base has a pyridine-like odor. The nitroprusside test was negative.

Action of *p*-Nitrobenzoyl Chloride on (II).—79.4 mg. of the hydrochloride was refluxed for one-half hour in pyridine solution with excess of *p*-nitrobenzoyl chloride. The reaction mixture was diluted with water and sodium carbonate was added. Extraction with ether and subsequent evaporation of solvent yielded 41.5 mg. of crystalline product (low yield indicative of side reaction). The 41.5 mg. was purified by dissolving in alcohol and adding water. Fine nearly white needles melting sharply at 131° were obtained and dried *in vacuo* at 55° for analysis; yield 22.7 mg. *Anal.* Calcd. for $C_{13}H_{12}N_2SO_4$: S, 10.97; N, 9.59. Found: S, 11.06; N (Dumas), 9.44. The *p*-nitrobenzoate is practically insoluble in water but soluble in ether, in alcohol, and readily in dilute hydrochloric acid. A crystalline hydrochloride was obtained by evaporating the hydrochloric acid solution.

Action of Nitrous Acid on (II).—A portion of the hydrochloride was treated in aqueous solution with sodium nitrite and the mixture extracted with ether. On evaporation of the ether an oil was obtained which in a few minutes changed to an ether-insoluble[13] crystalline mass. After crystallization from ethanol–ether the substance was dried at 55° *in vacuo*. *Anal.* Calcd. for $C_6H_9NSO \cdot HNO_3$: N, 13.59; S, 15.55. Found: N (Dumas), 13.33; S, 15.75. The above product is hygroscopic, sublimes when heated *in vacuo*, is almost insoluble in ether and chloroform, soluble in acetone and readily soluble in alcohol and water. The aqueous solution was found to have a strong acid reaction and to give a copious precipitate with nitron reagent. The nitrate of (II), prepared from the hydrochloride and the theoretical amount of silver nitrate, behaved in a similar fashion.

Action of Methyl Iodide on (II).—65.3 mg. of the hydrochloride was converted into the free base, which was then allowed to stand for two days at room temperature with excess methyl iodide. After removal of excess methyl

(8) H. T. Clarke and S. Gurin, THIS JOURNAL, **57**, 1876 (1935).

(9) A. Lieben, *Ann. Suppl.*, **7**, 231 (1870).

(10) R. R. Williams and A. E. Ruehle, THIS JOURNAL, **57**, 1856 (1935).

(11) All melting points in this paper are uncorrected.

(12) All nitroprusside tests in this paper were performed in a like manner except that much less substance was usually used.

(13) A somewhat similar phenomenon is described by Pummerer, *Ber.*, **43**, 1405 (1910).

iodide *in vacuo* the partly crystalline colored residue weighed 94.8 mg. This was purified by taking up in alcohol (acetone may be used) and precipitating with dry ether; 59.6 mg. of not quite colorless leaf-like crystals was obtained and a portion dried for analysis *in vacuo* at room temperature. *Anal.* Calcd. for $C_7H_{12}NSOI$: N, 4.91; S, 11.25. Found: N (Dumas), 4.70; S, 11.25. The methiodide is hygroscopic, quite insoluble in ether and chloroform, soluble in acetone and alcohol and readily soluble in water. It is extremely unstable toward alkali. A portion treated with 20% sodium hydroxide liberated no ether-soluble base but on standing at room temperature a dark tar was formed, insoluble in water and acid. The nitroprusside test was strongly positive. The methiodide as well as the other compounds described here has no vitamin B_1 activity.

Action of Nitric Acid on (II).—The hydrochloride of (II) was first converted into the nitrate or better into the free base and then oxidized with nitric acid (d. 1.42); 101 mg. of the hydrochloride gave with silver nitrate 115.7 mg. of the nitrate which was dissolved in 1 cc. of nitric acid. After short heating at 40° the reaction started, as evidenced by the darkening of the solution and the evolution of nitrogen oxides. The solution was kept at about 40° until no more gas bubbles formed and then most of the nitric acid was removed *in vacuo*. Quantitative removal of sulfate with baryta gave 50.2 mg. of barium sulfate. The remaining solution was evaporated to dryness, the residue suspended in water and extracted repeatedly with ether. Evaporation of the ether gave 42.0 mg. of white crystalline material which crystallized from methanol in cubes; yield 20.7 mg. After drying at 55° *in vacuo* it was analyzed. *Anal.* Calcd. for $C_5H_5NSO_2$: C, 41.93; H, 3.52; N, 9.79; S, 22.40. Found: C, 41.70; H, 3.51; N (Dumas), 9.20; S, 22.99. In later experiments it was found more convenient, instead of extracting the substance from its aqueous suspension with ether, to dissolve it in alkali and reprecipitate it by bringing to neutrality with acid. The properties of the substance are identical with those given by Windaus[7] for an acid of the same constitution obtained from the vitamin. It sublimes *in vacuo* at about 160°; on heating in a capillary tube it becomes colored above 200° and decomposes at about 250° with gas evolution. It is rather difficultly soluble in hot water and ether, soluble in alcohol and readily soluble in acids and in alkali. It gave a weak positive nitroprusside reaction. When heated with concentrated nitric acid no sulfate was formed. With ethereal diazomethane the methyl ester of m. p. 74° described by Windaus was obtained.

Action of Iodine and Alkali on (II).—The reaction was carried out on a 10-mg. portion of the hydrochloride according to the technique described by Mulliken.[14] No iodoform was formed.

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Summary

1. The basic cleavage product (II) gives on oxidation an acid C_4H_4NS—COOH identical with the product obtained by Windaus directly from the vitamin.

2. Evidence is presented for regarding (II) as a tertiary heterocyclic base with a β-hydroxyethyl side chain C_4H_4NS—CH_2CH_2OH.

3. Evidence is presented consistent with the view that the vitamin is a quaternary salt of the base (II).

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(14) "Identification of Pure Organic Compounds," John Wiley and Sons, Inc., New York, Vol. I, p. 166.

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF HARVARD UNIVERSITY]

The Synthesis of Phenanthrene and Hydrophenanthrene Derivatives. I. The Bougault Reaction

BY LOUIS F. FIESER AND EMANUEL B. HERSHBERG

In recent years γ-arylbutyric acids have acquired a position of considerable importance in the synthesis of polynuclear hydrocarbons, and several excellent methods have been developed for the preparation of these acids. Butyric acids of the benzene, naphthalene, phenanthrene, anthracene, and pyrene series are readily available as starting materials, as are many of their derivatives substituted in either the nucleus or the side-chain.[1] It occurred to us to submit some of these acids in the form of the esters to a special cyclization procedure which hitherto has been applied only to the simplest member of the series.

Bougault[2] discovered that the condensation product from β-phenylpropionic ester and oxalic ester is converted by concentrated sulfuric acid into the diester of indene-1,2-dicarboxylic acid,

(1) "Organic Syntheses," John Wiley and Sons, Inc., 440 Fourth Ave., New York City, 1935, Vol. XV, p. 64; Haworth and coworkers, *J. Chem. Soc.*, 1125, 1784, 2248, 2717, 2720 (1932); 1012 (1933); 454 (1934); Cook and Hewett, *ibid.*, 398 (1933); Cook and Haslewood, *ibid.*, 767 (1935); Fieser and Peters, THIS JOURNAL, **54**, 4347, 4373 (1932).

(2) Bougault, *Compt. rend.*, **159**, 745 (1915).