

The majority of the ortho substituted nitro compounds that do not hydrogenate readily are of the type known to exist as a chelated structure.

Platinum introduced as chloroplatinic acid acts as a true promoter, since through its action all nitro compounds that are hydrogenated with Raney nickel are hydrogenated more readily, while the platinum does not initiate reactions with compounds which are not hydrogenated by the catalyst alone.

The addition of a small amount (3 millimoles) of alkali to the reaction mixture usually retards the hydrogenation of nitro compounds. Contrary to the conclusion of Reasenberg this poisoning action is not limited to the neutral compounds. A few of the reactions with nitro compounds are promoted by the addition of alkali to the Raney nickel. This is particularly true in the case of the reduction of the nitroalkanes.

The fact that the addition of platinum tends to oppose the poisoning action of alkali gives support

to the idea that the action of both alkali and platinum are probably at the catalyst surface, and not due to the effect of the small amount of these substances upon the nitro compound undergoing reduction.

Summary

Data on the relative rates of hydrogenation with Raney nickel, and with Raney nickel treated with chloroplatinic acid and with alkali of 32 nitro compounds are presented.

Under the mild conditions of these experiments, the primary amine was obtained in almost quantitative yield. No evidence of the formation of intermediate compounds was observed.

The action of chloroplatinic acid and of alkali in the quantities used in these experiments and added just prior to the introduction of the hydrogen into the system, appears to exert their effect upon the catalyst surface rather than upon the nitro compound being hydrogenated.

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RECEIVED DECEMBER 2, 1949

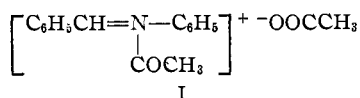
[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF THE UNIVERSITY OF PENNSYLVANIA]

The Addition of Acetic Anhydride to Benzalaniline. The Perkin Reaction in the Nitrogen System¹

By HENRY S. ANGEL AND ALLAN R. DAY

Although many writers have commented on the similarities in chemical behavior of the carbonyl group ($-\text{C}=\text{O}$) and the Schiff base linkage ($>\text{C}=\text{N}-$), there is little work reported on the Perkin reaction in the nitrogen system. Kalnin² heated benzalaniline, acetic anhydride and anhydrous potassium carbonate at 180° for fifteen minutes. He isolated a very small amount of cinnamic acid (4.3%) from the reaction mixture. He did not isolate any intermediates and the mechanism which he proposed appears to be highly improbable.³

Passerini and Macentelli⁴ heated benzalaniline with acetic anhydride for several minutes and isolated a forty per cent. yield of an addition product which they formulated as



This formula was proposed because of the ease with which the compound hydrolyzed to form acetanilide, benzaldehyde and acetic acid.

Later workers formulated the addition product

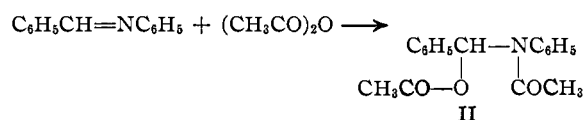
(1) From the Ph.D. Dissertation of Henry S. Angel.

(2) Kalnin, *Helv. Chim. Acta*, **11**, 977 (1928).

(3) Kalnin assumed that the carbon-hydrogen bond of the aldehyde group adds across the double bond of the enol form of the anhydride.

(4) Passerini and Macentelli, *Gazz. chim. ital.*, **58**, 64 (1928).

differently. Ekeley, Swisher and Johnson⁵ formulated the reaction as

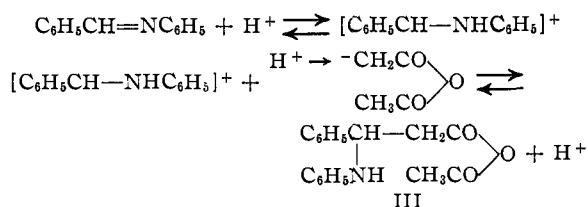


Snyder, Levin and Wiley⁶ accepted this formulation of the addition product but suggested a different course for its formation. Since the presence of acetic acid improved the yield of addition product, they proposed that the first step involves the addition of acetic acid to the double bond between carbon and nitrogen. This is followed by reaction with acetic anhydride to form the N-acetyl derivative (II). If this course of reaction were the correct one, one would assume that if the addition were carried out in the presence of acetic acid, benzoic acid and sulfuric acid, respectively, three different adducts might be obtained. Actually it is shown, in the present investigation, that the same adduct is formed in each case. Thus the acid must function solely as a catalyst for the addition of the anhydride to the Schiff base.

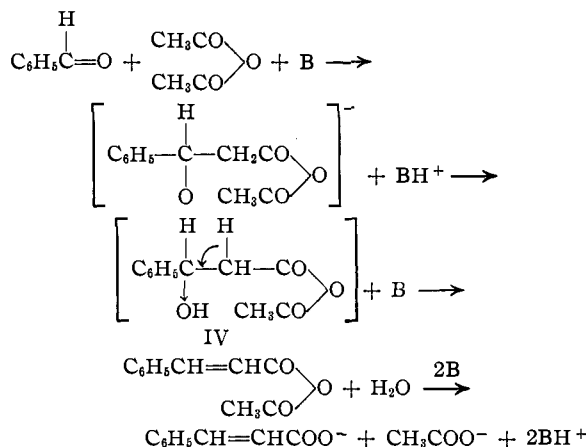
Previous workers apparently failed to notice the possibility of an aldol-type addition of the acetic anhydride to benzalaniline. Such an addition would be acid catalyzed and may be shown as

(5) Ekeley, Swisher and Johnson, *ibid.*, **63**, 81 (1932).

(6) Snyder, Levin and Wiley, *THIS JOURNAL*, **60**, 2025 (1938).



This course of reaction appeared reasonable not only because it is acid catalyzed but also because it agrees with the accepted mechanism for the Perkin reaction.⁷



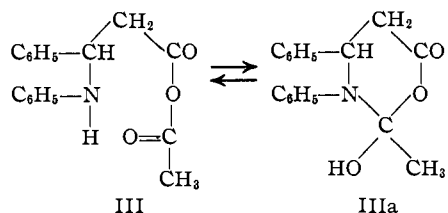
The intermediate IV has never been isolated. Water splits out spontaneously and hydrolyzes the resulting anhydride to cinnamic acid and acetic acid. Acetic β -anilinohydrocinnamic anhydride (III) is much more stable than the intermediate (IV) and can be isolated in good yields. The fact that the initial addition product of the Perkin reaction in the nitrogen system can be isolated is of interest since it supplies confirmatory evidence for the accepted mechanism of the Perkin reaction.

Acetic β -anilinohydrocinnamic anhydride, even when pure, when allowed to stand in the air undergoes a slow decomposition. This change involves the reversal of the aldol-type addition rather than deamination to form cinnamic acid. When heated with water, it decomposes rapidly and almost quantitatively to benzaldehyde, acetanilide and acetic acid. A similar change is produced when the addition product is dissolved in concentrated sulfuric acid and after standing for several hours is diluted with water. In this case benzaldehyde and aniline were isolated in nearly quantitative yields. In both cases the initial cleavage products probably were benzalaniline and acetic anhydride.

Benzalaniline and acetic anhydride were obtained in good yields when acetic β -anilinohydrocinnamic anhydride was heated, in the dry state, in a stream of nitrogen. Thus there

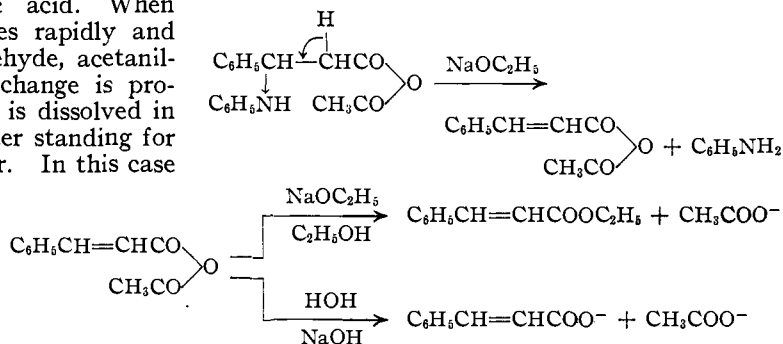
can be no doubt that this compound under acidic or neutral conditions cleaves to form the original reactants rather than splitting out aniline to form the normal end-product of a Perkin reaction.

The open chain structure (III) assigned to the adduct appears to be indicated by the cleavage reactions noted for acidic or neutral conditions. Since the addition product possesses both a secondary amine group and an acid anhydride grouping, however, it is possible that III is in equilibrium with an unstable cyclic structure IIIa. The latter may be considered as the intermediate of an acylation reaction.



It is not possible, at present, to say with certainty that the adduct is best represented as III, IIIa or an equilibrium mixture of the two. What is more important is the fact that either structure fits the data and the same fundamental principles are involved regardless of which form is used.

In view of Kalnin's work, it was thought that cinnamic acid might be obtained by heating III with anhydrous potassium carbonate. The results obtained, however, were essentially the same as when the heating was carried out in the absence of potassium carbonate and no cinnamic acid could be isolated. Better results were obtained by treating III with sodium ethoxide in ethanol at room temperature. Under these conditions it was possible to isolate ethyl cinnamate or cinnamic acid in yields of 21-45%. In every case fair yields of acetanilide were also formed. The formation of ethyl cinnamate is not surprising in view of the similarity in structure between the adduct III and the corresponding intermediate in the Perkin reaction.



The formation of acetanilide must be the result of an intramolecular acylation reaction. There appears to be no reason to believe that it is formed by the direct action of aniline on acetic cinnamic anhydride. Such a reaction might be expected

(7) Johnson, "Organic Reactions," Vol. I, John Wiley and Sons, Inc., New York, N. Y. 1942.

Acid Catalyzed Decomposition of Acetic- β -anilinohydrocinnamic Anhydride.—The addition product was added slowly to five molar equivalents of concentrated sulfuric acid. Solution took place slowly, with shaking, and was complete in about three hours. After sixteen hours a mass of fine needles had separated. Ice was added slowly, with shaking, keeping the temperature below 30°. The mixture was then steam distilled and the distillate treated with acetic acid and phenylhydrazine. Benzaldehyde phenylhydrazone was obtained in almost quantitative yield. After recrystallization from alcohol it melted at 156–157°. The residue from the steam distillation was made alkaline and again steam distilled. The aniline in the distillate was precipitated as its tribromo derivative, yield 80%. After recrystallization from alcohol, it melted at 120–121° cor.

Cleavage of Acetic- β -anilinohydrocinnamic Anhydride by the Action of Heat.—The anhydride (0.118 mole) was heated, in a stream of nitrogen. The temperature was slowly raised to 225° and kept at this temperature for 20 minutes. During this period, 10.6 g. of distillate collected in the receiver. This distillate gave a 90% yield of acetanilide, m. p. 113–114°, when treated with aniline. The 10.6 g. of acetic anhydride corresponds to 0.104 mole.

The residue from the above heat treatment weighed 21.1 g. and melted at 48–51°. After recrystallization from 80% alcohol it melted at 51–52° cor. It gave no melting point depression with an authentic sample of benzalaniline. The benzalaniline was isolated from the residue in a 92% yield.

When the above experiment was repeated in the presence of anhydrous potassium carbonate, somewhat similar results were obtained. Only a small amount of acetic anhydride distilled over but a fair yield of benzalaniline was obtained from the residue. No cinnamic acid could be isolated.

Base-Catalyzed Cleavage of Acetic β -Anilinohydrocinnamic Anhydride.—The reaction product from benzalaniline and acetic anhydride was treated with 2 molar equivalents of sodium ethoxide in ethanol. On standing for sixteen hours, a reddish color had developed and the solution had set to gel. The mixture was diluted with water, refluxed for one hour and steam distilled. The distillate was extracted with ether and the latter then extracted with dilute hydrochloric acid. The acid extract was made alkaline and steam distilled. From this distillate 0.29 equivalent of aniline was recovered as tribromoaniline; m. p. after recrystallization from alcohol, 120.5–121.5° cor. On distillation of the ether extract 0.049 of an equivalent of benzaldehyde was obtained and identified as its phenylhydrazone.

The residual solution from the first steam distillation deposited fine needles on cooling. It was identified as acetanilide (0.463 equivalent), m. p. 113–114°, mixed melting point, 113–114°. The filtrate from the acetanilide on acidification with hydrochloric acid gave 0.458 of an equivalent of cinnamic acid. After recrystallization from boiling water, it melted at 133.5–134.5°, mixed melting point 133–134°.

In another experiment, only one molar equivalent of sodium ethoxide was used and the yield of cinnamic acid dropped to 28.4%. In these two experiments the reaction mixture, after standing, was diluted with water and refluxed in order to hydrolyze the ethyl cinnamate formed.

Preparation of Ethyl β -Anilinohydrocinnamate.—Acetic β -anilinohydrocinnamic anhydride (20 g.) was refluxed for 45 minutes with 17 cc. of dry ethanol. On cooling, crystals were deposited. They were removed and washed with cooled petroleum ether, yield 85%. The product may be recrystallized from either cyclohexane or high boiling petroleum ether, m. p. 80–81° cor. *Anal.* Calcd. for $C_{17}H_{19}NO_2$: C, 78.84; H, 7.06; N, 4.95. Found: C, 78.78; H, 7.01; N, 5.04. The ester is quite stable and distills at 306–310° at 760 mm. without decomposing. It is also volatile with steam. An attempt to carry out the esterification in the presence of a trace of concentrated sulfuric acid was unsuccessful. An almost quantitative yield of acetanilide was obtained.

Acid-Catalyzed Cleavage of Ethyl β -Anilinohydrocinnamate.—The ester was dissolved in a minimum amount of concentrated sulfuric acid. After standing for thirty minutes the solution was diluted with water and steam distilled. A 96% yield of benzaldehyde was isolated, from the distillate, in the form of its phenylhydrazone; m. p. 156–157°, after recrystallization from 75% alcohol. The residual solution from the steam distillation was treated with bromine to precipitate tribromoaniline. The weight of this precipitate corresponded to an 88% yield of aniline; m. p. 120.5–121.5°, after recrystallization from alcohol.

If the solution of the ester is diluted with water and filtered, instead of steam distilling, 60–65% yields of acetanilide are obtained.

Base-Catalyzed Cleavage of Ethyl β -Anilinohydrocinnamate.—Attempts to cleave the ester by refluxing with 10–25% sodium hydroxide solutions were unsuccessful, the ester being almost quantitatively recovered. Refluxing the ester in ethanol containing a molar equivalent of sodium ethoxide produced cleavage. On cooling the alcohol solution, 50–60% yields of acetanilide separated.

Summary

1. It has been shown that the addition of acetic anhydride to benzalaniline is an acid catalyzed reaction and forms acetic β -anilinohydrocinnamic anhydride. This compound represents the initial addition product of the Perkin reaction in the nitrogen system.

2. The addition product may be converted to the starting materials by heat alone or by treating with aqueous acids.

3. The addition product is converted to the normal end-product of the Perkin reaction, cinnamic acid, by treatment with sodium ethoxide.