[CONTRIBUTION FROM THE INSTITUTE OF PAPER CHEMISTRY]

Reactions of Vanillin and its Derived Compounds. II. The Reaction of Vanillin with Alkali and Silver Nitrate[1,2]

BY IRWIN A. PEARL

When vanillin is treated with washed silver oxide and an excess of alkali, vanillic acid is formed.[2] However, when silver nitrate is added to an aqueous solution of vanillin in an excess of alkali, separation of a fluffy silver metal takes place, and when the solution is acidified with a non-reducing acid, 5-nitrovanillic acid is obtained in addition to vanillic acid. Acidification with sulfur dioxide yields only vanillic acid. Since the addition of sodium nitrite, but not of sodium nitrate to an acid solution of vanillic acid yields 5-nitrovanillic acid, it was assumed that in the oxidation of vanillin with alkali and silver nitrate some nitrite is produced by the reduction of the nitrate by active metallic silver. This assumption was proved by an experiment in which active silver metal was added to an alkaline solution of vanillic acid and sodium nitrate.

The addition of sodium nitrite to an acid suspension of vanillic acid gave an excellent yield of 5-nitrovanillic acid[3] and a little 4,6-dinitroguaiacol. The latter substance was undoubtedly formed by decarboxylation of 5-nitrovanillic acid, and was formed in quantitative yield by treating vanillic acid with nitric acid at 10–15°.

Experimental

All melting points are uncorrected.

Reaction of Vanillin with Alkali and One Mole of Silver Nitrate.—To 400 g. of water were added with vigorous stirring 48.0 g. (1.2 moles) of sodium hydroxide and 30.4 g. (0.2 mole) of vanillin. The temperature of the solution at that point was 55°. With continued agitation, a solution of 34.0 g. (0.2 mole) of silver nitrate in 150 g. of water previously warmed to 55° was added. Silver oxide was momentarily formed as a granular brownish-black powder, but at approximately the same moment reaction set in, the temperature rose to 85°, and the silver oxide was decolorized with the production of fluffy, spongy metallic silver. The reaction mixture was filtered hot and washed with water. The alkaline filtrate was acidified with sulfur dioxide and, after cooling, the white crystalline precipitate was filtered, washed with water, and dried, yielding 31.4 g. (93.2%) of pure vanillic acid, m. p. 210–211°. Ether extraction of the aqueous filtrate and washings yielded an additional 2.3 g. (6.8%) of vanillic acid.

The precipitated silver obtained in this reaction appeared to have a much lower apparent specific gravity than fluffy silver metals previously prepared.[2] Upon drying of this silver metal at 50°, it became spontaneously heated above its melting point and appeared as a small fused ball of metallic silver. This silver metal could be preserved only in the moist condition.

If cold solutions of silver nitrate and of alkali and vanillin were mixed, a silver oxide separated, but the oxidation reaction did not take place until the resulting mixture was warmed to 50–55°. Under these conditions, the silver metal obtained was similar to that obtained in the isolated silver oxide oxidations of vanillin.[2] Addition of a hot solution of silver nitrate to a hot alkaline solution of vanillin resulted in very vigorous to violent reactions which approached the uncontrollable stage as the temperature approached 70–80°. Under these conditions, the fluffy silver metal obtained was very active and was unstable if allowed to dry.

Acidification of Silver Nitrate-Alkali-Vanillin Oxidation Mixture with Hydrochloric Acid.—The above reaction was repeated, but the alkaline filtrate and washings were acidified with hydrochloric acid. A dark solution and a light yellow precipitate resulted. The mixture was filtered and the precipitate was washed with water and dried. The filtrate and washings were extracted with ether and the ether was dried and distilled. A total of 34.2 g. of yellow crystals melting at 207–210° was obtained. Recrystallization from water in the presence of decolorizing carbon yielded 29.4 g. (87.5%) of vanillic acid melting at 210–211°. Extraction of the carbon with methanol and precipitation with water yielded 2.1 g. (4.9%) of 5-nitrovanillic acid as bright yellow crystals melting at 214–215°.

Anal. Calculated for $C_8H_7O_6N$: C, 45.08; H, 3.31. Found: C, 45.12; H, 3.31.

5-Nitrovanillic Acid in Acidified Vanillic Acid Reaction Mixtures.—A solution of 16.8 g. (0.1 mole) of vanillic acid, 10.0 g. (0.25 mole) of sodium hydroxide, and 8.5 g. (0.1 mole) of sodium nitrate in 300 g. of water at 20° was treated with an excess of 18 *N* sulfuric acid with stirring. After several drops of acid were added, white vanillic acid began to separate. After several hours of stirring, the mixture was filtered. A substantially quantitative recovery of vanillic acid melting at 210–211° was obtained. No trace of the yellow 5-nitrovanillic acid was apparent.

The above reaction mixture, containing in addition 1 g. of sodium nitrite, yielded 16.9 g. of yellow crystals melting at 206–210° upon acidification with sulfuric acid under the same conditions. Recrystallization from water in the presence of decolorizing carbon and extraction of the carbon as described above yielded 14.4 g. (86%) of vanillic acid, m. p. 210–211° and 1.1 g. (5.2%) of 5-nitrovanillic acid, m. p. 214–215°.

The same results were obtained by adding several grams of the moist fluffy metallic silver metal to the original aqueous mixture of vanillic acid, sodium hydroxide, and sodium nitrate at 60° and, after cooling, acidifying with sulfuric acid.

A solution of 16.8 g. of vanillic acid, 10.0 g. of sodium hydroxide, and 6.9 g. (0.1 mole) of sodium nitrite in 300 g. of water at 20° was acidified with 18 *N* sulfuric acid. Brown fumes were evolved and the white precipitate, which separated immediately upon acidification, gradually changed to bright yellow needles. After standing for two hours, the mixture was filtered. Recrystallization of the precipitate from water yielded 16.1 g. of yellow needles melting at 126–160°. The crude product was extracted with hot ligroin, and the extracted solids were recrystallized from petroleum ether to give 1.8 g. (8.4%) of 4,6-dinitroguaiacol, m. p. 123–124°.

Anal. Calculated for $C_7H_6O_6N_2$: C, 39.26; H, 2.83. Found: C, 39.58; H, 2.76.

The residue from the ligroin extraction was dissolved in 8% sodium bicarbonate solution, filtered, and acidified with dilute sulfuric acid. The yellow precipitate was

---

[1] This paper represents a portion of the results obtained in the research program sponsored by the Sulphite Pulp Manufacturers' Committee on Waste Disposal and conducted for the Committee by The Institute of Paper Chemistry. Acknowledgment is made by the Institute for permission on the part of the Committee to publish these results.

[2] For Part I, see Pearl, THIS JOURNAL, **68**, 429 (1946).

[3] Klemenc, *Monatsh.*, **35**, 93 (1914), obtained small amounts of 5-nitrovanillic acid from vanillic acid by other methods.

filtered, washed with water, and recrystallized from water in the presence of decolorizing carbon. A yield of 13.8 g. (65%) of 5-nitrovanillic acid as light yellow needles melting at 214–215° and not depressing a mixed melting point with authentic 5-nitrovanillic acid was obtained.

Reaction of Vanillic Acid with Nitric Acid.—A suspension of 5 g. of vanillic acid and several pieces of ice in 150 cc. of water was placed in a beaker surrounded by an ice-bath. While the temperature was maintained between 10 and 15°, 200 cc. of 1:1 nitric acid was stirred in. Very little reaction took place. After all the nitric acid was added, the mixture was warmed to 35°, at which temperature the white vanillic acid precipitate turned yellow in color. The yellow mixture was stirred at room temperature for one hour, and then poured into an excess of cold water. The bright yellow crystalline precipitate was filtered, washed with water, and dried in a vacuum desiccator. A yield of 6.3 g. of yellow crystals melting at 121–124° was obtained. Recrystallization from water yielded yellow needles melting at 123–124°, which did not depress a mixed melting point with authentic 4,6-dinitroguaiacol. The yield was substantially quantitative.

Summary

Vanillic acid has been prepared by oxidizing vanillin with alkali and one mole of silver nitrate and acidifying with sulfur dioxide. Non-reducing acids yielded, in addition, a small amount of 5-nitrovanillic acid. The mechanism of the formation of 5-nitrovanillic acid has been ascertained. 5-Nitrovanillic acid and 4,6-dinitroguaiacol have been prepared from vanillic acid.

APPLETON, WISCONSIN RECEIVED DECEMBER 31, 1945

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF THE STATE UNIVERSITY OF IOWA]

Syntheses of δ-Cyclopentyl-*n*-valeric Acid[1]

BY GEORGE H. COLEMAN, JOSEPH E. CALLEN AND CLINTON A. DORNFELD

In this Laboratory we recently had occasion to prepare a quantity of δ-cyclopentyl-*n*-valeric acid. Because the best method[2] previously reported, a six-step procedure starting from bromocyclopentane and involving Grignard reactions with ethylene oxide, gives an over-all yield of only 7–12%, and because a preliminary investigation of a three-step procedure[3] involving the reaction of cyclopentylmagnesium bromide with furfural was not encouraging, other methods of preparation were studied. Of these methods, two were finally used. One synthesis consisted of the following three steps: reaction of cyclopentylmagnesium bromide with γ-chloropropyl *p*-toluenesulfonate to yield γ-chloropropylcyclopentane, condensation with malonic ester to give ethyl γ-cyclopentylpropylmalonate, and hydrolysis and decarboxylation to δ-cyclopentyl-*n*-valeric acid. A yield of only 19% of γ-chloropropylcyclopentane was obtained in the first step although better results for this type of reaction have been reported.[4]

It was found more feasible to obtain the γ-halopropylcyclopentane required for the synthesis by another method involving the following two steps: reaction of cyclopentylmagnesium bromide with allyl bromide to form allylcyclopentane, and addition of hydrogen bromide in the presence of oxygen to give γ-bromopropylcyclopentane.[5] Allylcyclopentane was obtained by a modification of the method of Piaux and Bourguel.[6] A malonic ester synthesis with the γ-bromo compound resulted in δ-cyclopentyl-*n*-valeric acid in 29% over-all yield. The products obtained by the two methods were identical and corresponded in properties and derivatives to the literature values.

In the reaction of hydrogen bromide with allylcyclopentane there was formed in addition to γ-bromopropylcyclopentane some slightly lower boiling material, probably β-bromopropylcyclopentane. In several trial runs, benzoyl peroxide (one mole per cent.) was used to orient the entering hydrogen bromide, but oxygen was found to give equally good yields of the desired isomer.

In one of the preliminary runs, the bromopropylcyclopentane was not fractionated, but was carried directly through the malonic ester synthesis to the acid. The product was a mixture of acids from which the δ-cyclopentyl-*n*-valeric acid was obtained by a careful fractionation.

Experimental

γ-Chloropropylcyclopentane.—(*Cf.* ref. 4.) To a solution of cyclopentylmagnesium bromide, prepared from 100 g. (0.67 mole) of bromocyclopentane,[7] 16.3 g. (0.67 mole) of magnesium, and 300 ml. of dry ether, was added slowly 307 g. (1.23 moles) of γ-chloropropyl *p*-toluenesulfonate[4] with 500 ml. of dry ether, and the mixture was heated at reflux for twelve hours. The reaction mixture was decomposed with ice, and 6 *N* hydrochloric acid was added until the precipitate dissolved. The ether layer was separated and the aqueous layer extracted with ether. By fractional distillation of the combined ether extracts, 18.6 g. (19%) of γ-chloropropylcyclopentane was obtained, b. p. 83–87° (22.5 mm.), n^{25}D 1.4582.

Allylcyclopentane.[6]—To a filtered solution of cyclopentylmagnesium bromide, prepared from 125 g. (5 moles) of magnesium, 745 g. (5 moles) of bromocyclopentane, and 3100 ml. of anhydrous ether, was added slowly with

---

[1] The work described in this paper was done under a contract, recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and the State University of Iowa.

[2] Yohe and Adams, THIS JOURNAL, **50**, 1503 (1928).

[3] Katsnel'son and Kondakova, *Comp. rend. acad. sci. U. R. S. S.*, **17**, 367 (1937).

[4] Rossander and Marvel, THIS JOURNAL, **50**, 1491 (1928).

[5] Since this work was completed the preparation of γ-bromopropylcyclopentane by nearly the same method has been reported: Whitmore, Herr, Clark, Rowland and Schiessler, *ibid.*, **67**, 2059 (1945).

[6] Piaux and Bourguel, *Ann. chim.*, [11] **4**, 216 (1935).

[7] Noller and Adams, THIS JOURNAL, **48**, 1084 (1926).