

[CONTRIBUTION FROM THE STERLING CHEMISTRY LABORATORY, YALE UNIVERSITY]

The Rosenmund Reduction of Undecylenoyl Chloride

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The Rosenmund reduction of acyl chlorides to the corresponding aldehydes has been applied to some unsaturated acyl chlorides¹ and found to yield the expected unsaturated aldehydes, apparently without appreciable rearrangement or reduction of the double bond. In connection with the synthesis of unsaturated acids related to traumatic acid² the application of this reaction to undecylenoyl chloride has been investigated.

It was found that reduction of undecylenoyl chloride in the usual manner with a palladium-barium sulfate catalyst in boiling xylene resulted in the formation of an unsaturated aldehyde in 55% yield. The product polymerized readily,³ and hence was converted by Claisen's method⁴ to the corresponding diethyl acetal for analysis and purification. Quantitative hydrogenation of the undecylenyl aldehyde diethyl acetal so produced revealed the presence of about 10% of saturated material; this was apparently undecylaldehyde diethyl acetal produced by partial reduction of the double bond. It was found, however, that the bromine adduct of this undecylenyl aldehyde diethyl acetal yielded no terminal acetylenic product when treated with alcoholic potassium hydroxide by the method of Krafft;⁵ the mixture of acetylenic acetals obtained did not react with silver nitrate or evolve methane in the Zerewitinoff apparatus. By analogy with the cases reported by Krafft,⁵ and our own experience, about a 30-40% yield of undecyne-1-al-11 diethyl acetal would have been expected.

An ozonolysis of the above undecylenyl aldehyde revealed that both partial reduction and extensive rearrangement of the double bond had occurred during the Rosenmund reduction. The products isolated from ozonolysis and subsequent oxidation were undecylic, azelaic and suberic acids; no sebacic acid, the expected product, could be obtained. This indicates that the double bond had rearranged almost completely from its original 10,11-position to the 8,9- and 9,10-positions. The possibility of the formation of much smaller amounts of other isomers in which the double bond had migrated still further down the carbon chain has not been excluded by these experiments, but degradation products corresponding to such isomers were not isolated.

The observed rearrangement is similar to that reported by Hilditch and Vidyarthi⁶ in their study of the partial reduction of some unsatu-

rated fatty acids. These investigators found evidence for a somewhat less extensive migration of double bonds under the influence of nickel catalysts at elevated temperatures in the presence of limited amounts of hydrogen.

It has been found that addition of bromine to undecylenoyl chloride removes the possibility of rearrangement and allows reduction of the acyl chloride group to the aldehyde stage. By treating the resulting dibromo undecylenyl aldehyde diethyl acetal with alcoholic potassium hydroxide undecyne-10-al-1 diethyl acetal has been obtained.

Experimental

Rosenmund Reduction of Undecylenoyl Chloride.—Undecylenic acid was converted to its acid chloride by refluxing on the steam-bath with 1.2 moles of thionyl chloride for one hour. Undecylenoyl chloride, b. p. 102° at 2 mm., n_D^{20} 1.4552, was obtained in about 80% yield.

The above product, 100 g., was dissolved in 300 cc. of dry xylene containing 0.5 g. of 5% palladium on barium sulfate and 0.1 g. thiourea.⁷ Hydrogen was passed rapidly through the refluxing solution until the evolution of hydrogen chloride had almost ceased (about three hours). Measurement of the evolved hydrogen chloride by titration indicated that 70-80% of the theoretical amount had been liberated at this point. Fractionation of the filtered reaction mixture gave 45 g., 55% of the theoretical amount, of unsaturated aldehyde; b. p. 103° at 9 mm.; n_D^{20} 1.4464; d_4^{20} 0.8496; *MR*, calcd. 52.54, found 52.73. On standing at room temperature overnight a freshly distilled sample, n_D^{20} 1.4414, showed a rise in refractive index to n_D^{20} 1.4492.

Attempted Preparation of Undecyne-10-al-1 Diethyl Acetal.—In view of the rapid polymerization of the above aldehyde it was converted at once without distillation to the corresponding acetal by warming on the steam-bath for fifteen minutes with 65 g. of ethyl orthoformate, 120 cc. of absolute ethanol, and 3 drops of concentrated sulfuric acid. To ensure removal of any unchanged esters and acids, the mixture was then heated with an excess of 10% aqueous potassium hydroxide solution for thirty minutes longer. After removal of the alcohol *in vacuo*, the aqueous alkaline solution was extracted with ether. Upon evaporation of the dried ether solution and distillation of the product there was obtained 60 g. of a mixture of isomeric undecylenic aldehyde diethylacetals; b. p. 109-111° at 11 mm.; n_D^{20} 1.4350.

Anal. Calcd. for $C_{15}H_{30}O_2$: C, 74.35; H, 12.38. Found: C, 74.04; H, 12.53. 0.1132 g. took up 9.30 cc. of H_2 at 23° at 750 mm. in ethanol solution. Calcd. for one double bond: 10.4 cc.

This product when brominated and treated as described below in the preparation of undecyne-10-al-1 diethyl acetal gave no evidence for the formation of any 1-acetylenic products.

Ozonolysis of Undecylenoyl Chloride Reduction Products.—The reaction mixture obtained as described above from 150 g. of undecylenoyl chloride after filtration and evaporation of most of the xylene, was shaken with potassium hydroxide solution to remove unreacted undecylenoyl chloride. The crude aldehyde mixture was then added to a solution of 150 g. of silver nitrate, 50 g. of potassium hydroxide and 200 cc. of concentrated ammonia in about one liter of dilute alcohol. The homogeneous solution

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(2) J. English, Jr., *THIS JOURNAL*, **63**, 941 (1941).

(3) C. Grundman, *Ann.*, **31**, 524 (1936).

(4) L. Claisen, *Ber.*, **40**, 3903 (1907).

(5) F. Krafft, *ibid.*, **29**, 2236 (1896).

(6) F. P. Hilditch and N. L. Vidyarthi, *Proc. Roy. Soc. (London)*, **A122**, 522 (1929).

(7) C. Weygand and W. Meusel, *Ber.*, **76**, 503 (1943).

was allowed to stand overnight, filtered and evaporated. By ether extraction and separation into neutral and acid fractions there was obtained 75 g. of crude acids.

The crude acids were then dissolved in 200 cc. of chloroform, ozonized at -10° , and the ozonide decomposed with silver oxide and sodium hydroxide by the method of Asinger.⁸ There was obtained a mixture of acids, 55 g., which was esterified with methanol and sulfuric acid in the usual manner.

Fifty grams of the mixture of methyl esters so obtained was fractionated through a 24×0.5 inch column packed with single-turn glass helices. Three main fractions were obtained.

Fraction I, 8 g., b. p. $84-90^{\circ}$ at 1.3 mm.; n^{22}_{D} 1.4315, consisted mostly of methyl undecylate. Saponification and redistillation of the free acid gave impure undecylic acid, m. p. 24° , equivalent weight by titration 174. This material apparently originated from partial reduction of the double bond during the Rosenmund process.

Fraction II, 11 g., b. p. 92° at 1.6 mm. to 98° at 0.9 mm.; n^{22}_{D} 1.4335-1.4348. This fraction was saponified and the crude acids so obtained extracted twice with hot chloroform to remove some azelaic acid. After one recrystallization from water there was obtained 5 g. of suberic acid, m. p. $138-140^{\circ}$, equivalent weight 87.4. Attempts to recover lower dibasic acids from the mother liquors failed to yield any pure products.

Fraction III, 21 g., b. p. 104° at 0.9 mm.; n^{22}_{D} 1.4360. This fraction was almost pure azelaic acid methyl ester. Saponification of 2.0 g. of this fraction yielded 1.68 g. of azelaic acid, m. p. 106° without purification. Equivalent weight by titration was 94.3. This product gave no depression of m. p. with an authentic sample of azelaic acid. A separate hydrolysis of the top 0.5 g. of this fraction, obtained by distillation from a smaller apparatus, gave an acid, m. p. 102° , equivalent weight 94.2, which was nearly pure azelaic acid, indicating little if any sebacic acid was present in the mixture. A non-volatile residue, 3-4 g., was not identified.

Undecyne-10-al-1 Diethyl Acetal.—Undecylenoyl chloride, 30 g., dissolved in 90 cc. of dry xylene was treated

at 0° with 24 g. of bromine. From the amount of hydrogen bromide evolved during this reaction it was evident that substitution had taken place to the extent of about 10% of the amount of bromine used. Palladium-barium sulfate catalyst, 1 g., was then added and the reduction carried out as usual. The addition of thiourea "poison" made no difference in the final product in this case. Hydrogen chloride corresponding to 75% of the theoretical amount was evolved as before in the course of three hours, after which time the reaction had almost stopped. After filtration of the catalyst and evaporation of the solvent *in vacuo* there was added 20 g. of ethyl orthoformate and 35 cc. of absolute ethanol containing 3 drops of concentrated sulfuric acid. The mixture was refluxed for half an hour on the steam-bath. A solution of 60 g. of potassium hydroxide in 200 cc. of 95% ethanol was then added and the mixture allowed to stand overnight at room temperature.⁵ After refluxing for eight hours to complete the elimination of hydrogen bromide, the alcohol was evaporated and the undecyne-10-al-1 diethyl acetal isolated by distillation through a small fractionating column.⁹ There was obtained 8.5-9.0 g. of undecyne-10-al-1 diethyl acetal, b. p. 104° at 1.2 mm.; n^{22}_{D} 1.4410.

Anal. Calcd. for $C_{15}H_{28}O_2$: C, 74.90; H, 11.64; C_2H_5O , 37.5. Found: C, 74.30; H, 11.90; C_2H_5O , 38.9. 0.0226 g. gave 2.03 cc. of methane at 24° , 760 mm.; calcd. for one active H, 2.27 cc. 0.1090 g. absorbed 22.0 cc. hydrogen at 22° , and 770 mm. in ethanol; calcd. 22.0 cc.

Summary

It has been shown that the double bond of undecylenoyl chloride migrates during Rosenmund reduction.

Ozonolysis of the unsaturated aldehyde so obtained yielded suberic and azelaic acids but no detectable sebacic acid.

Undecyne-10-al-1 diethyl acetal has been prepared.

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A New Synthesis of β -Alanine

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In view of the importance of β -alanine in the synthesis of pantothenic acid, various new syntheses of this amino acid have been proposed. The starting material which attracted most attention in this connection was the inexpensive and now readily available acrylonitrile.¹ Unfortunately, the most promising method, that involving the interaction of acrylonitrile with ammonia, suffers from the disadvantage of relatively low yields (the highest reported is 39%), the necessity of separating large amounts of secondary amine and the instability of the crude β -amino-propionitrile. These drawbacks complicate this process considerably, particularly in its application to the large scale production of β -alanine.

The conversion of β -amino-propionitrile to the free amino-acid also presents certain difficulties.

Hydrolysis with hydrochloric acid yields β -alanine hydrochloride which is treated with lead or silver oxide in order to obtain the free acid. A less tedious method which involves the use of ion exchange resins has been recently described.² Its chief disadvantage lies in the high dilutions employed. A more recent method uses alkaline hydrolysis with barium hydroxide.³ However, considerable amounts of alkali are necessary for good yields and their subsequent removal in the form of barium carbonate is inconvenient on a large scale.

The present paper describes a method which gives high yields of β -alanine hydrochloride from acrylonitrile and phthalimide by a combination of a Michael condensation and the Gabriel synthesis. It also describes a simple procedure for

(1) U. S. Patents 1,992,615; 2,334,163; 2,335,605; 2,335,653; 2,335,997; 2,336,067; *THIS JOURNAL*, **66**, 725 (1944).

(2) Buc, Ford and Wise, *ibid.*, **67**, 72 (1945).

(3) Ford, *ibid.*, **67**, 876 (1945).