also be prepared directly from the oxazoline, in 95% yield. A mixed m. p. with the product prepared by acylation of *cis*-2-aminocyclohexanol (from 2-acetaminophenol) was undepressed.

Anal. Calcd. for $C_{13}H_{16}O_4N_2$: C, 59.2; H, 6.12; N, 10.6. Found: C, 59.4; H, 6.03; N, 10.5.

***d,l-cis*-2-Aminocyclohexanol Hydrochloride.**—(a) Two grams of the *cis-p*-nitrobenzamide was refluxed in 15 ml. of 4 *N* hydrochloric acid for three hours. After removal of *p*-nitrobenzoic acid, the solution was basified and extracted with chloroform–ether (1:1). The dried extract was saturated with dry hydrogen chloride, yielding the amino-alcohol salt, which was recrystallized from ethanol-benzene (1:5), giving 0.75 g. of colorless leaflets, m. p. 185–190°. A portion of the product was benzoylated and a mixed m. p. with the product (N-benzoyl) obtained from hydrogenation of 2-acetaminophenol was not depressed. (b) Hydrolysis of either the oxazoline or the amino-ester hydrochloride for five hours with 4 *N* hydrochloric acid gave 75 and 73% yields, respectively, of the same product.

Reaction of *cis*-2-*p*-Nitrobenzoylaminocyclohexanol with Thionyl Chloride.—The procedure used for the *trans* isomer gave only starting material at room temperature, and at higher temperatures extensive decomposition resulted.

Reactions of Oxazolines in Acetic Acid Solutions

Retention of Configuration with Wet Acetic Acid-Sodium Acetate: Formation of *d,l,cis*-2-*p*-Nitrobenzoylaminocyclohexanol.—A solution of 0.95 g. of acetic acid, 0.05 g. of water, 0.1 g. of fused sodium acetate, and 0.2 g. of the oxazoline was refluxed for three hours. The solution was cooled, and made alkaline with sodium carbonate. The white precipitate was recrystallized from dilute ethanol, giving 0.13 g. of colorless needles, m. p. 174–176°. A mixed m. p. with an authentic sample of *cis*-2-*p*-nitrobenzoylaminocyclohexanol was not depressed.

Inversion of Configuration with Dry Acetic Acid–Sodium Acetate: Formation of *d,l-trans*-2-*p*-Nitrobenzoylaminocyclohexyl Acetate.—An anhydrous solution was prepared by refluxing for two hours a mixture of 9.5 ml. of glacial acetic acid, 0.5 ml. of acetic anhydride and 1.0 g. of fused sodium acetate. A 1-ml. aliquot of this solution was added to 0.40 g. of the oxazoline, and the mixture refluxed four hours with exclusion of moisture. The resultant solution was cooled, and diluted with 4.0 ml. of water, giving a colorless oil, which solidified within half an hour. The solid was collected, and washed with 5 ml. of 5% hydrochloric acid. Recrystallization from absolute ethanol gave 0.20 g. of colorless prisms, m. p. 173–178°. A further recrystallization gave 0.12 g., m. p. 178–180°. A mixed m. p. with *trans*-2-*p*-nitrobenzoylaminocyclohexyl acetate was not depressed. (Basification of the above acid washings gave 30 mg. of unchanged starting material.)

The identity of the product was confirmed by hydrolysis of a portion with dilute alcoholic sodium hydroxide at 25° to *trans*-2-*p*-nitrobenzoylaminocyclohexanol. A mixed m. p. with an authentic sample was not depressed.

Summary

1. *trans*-2-Acylaminocyclanols react with thionyl chloride to give 4,5-*cis*-cycloalkanoöxazolines, which are easily hydrolyzed to *cis*-2-aminocyclanols. Configurations are discussed in relation to probable mechanisms.[23]

2. 2-*p*-Nitrophenyl-4,5-*cis*-cyclohexanoöxazoline reacts with dry sodium acetate–acetic acid with inversion to give primarily *trans*-2-acylaminocyclohexyl acetate. The presence of a small amount of added water changes the product to *cis*-2-acylaminocyclohexanol.

3. The O–N interatomic distance has been calculated for equatorial-polar and chair-boat tautomers of *cis* and *trans* 2-aminocyclohexanol. The results may aid in predicting the ease of formation of heterocyclic rings fused to cycloalkane rings.

[23] McCasland, Clark and Carter[2a]; *cf.* Winstein, *et al.*, THIS JOURNAL, **64**, 2796 (1942).

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[CONTRIBUTION FROM THE WM. H. CHANDLER CHEMISTRY LABORATORY, LEHIGH UNIVERSITY]

Reactions in the β-Furan Series—Synthesis and Reactions of 3-Chloromethylfuran and Some Related Compounds

BY EDWARD SHERMAN[1] AND E. D. AMSTUTZ

α-Furfuryl chloride is an interesting substance because of the various factors which contribute to its unique chemical characteristics. Thus it possesses the simple allylic structure, an extended allylic system and the β-halogen ether grouping. In order better to understand the contributions of these various systems toward the chemical behavior of the molecule in reaction we undertook the study of the isomeric halide, β-furfuryl chloride. Since the latter substance, which possesses only an allylic system, now proves to have a close relationship not only to α-furfuryl chloride but also to β-thenyl chloride, benzyl chloride and cinnamyl chloride the pertinent chemistry of these materials is briefly reviewed.

When α-furfuryl chloride was treated with strong aqueous potassium cyanide,[2] there was obtained a mixture of nitriles[3] reported[4] to consist of approximately 85% of 5-methyl-2-furonitrile and 15% of 2-furylacetonitrile. Under comparable conditions, 3-thenyl bromide has been reported[5] to yield, on subsequent hydrolysis, only 3-thienylacetic acid. Scott[6] was unable to detect the presence of "abnormal" products (*i. e.*, products of allylic reaction) in the reaction of benzyl chloride

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[1] (a) Taken in part from a dissertation presented by Edward Sherman to the Graduate Faculty of Lehigh University in partial fulfillment of the requirements for the degree of Doctor of Philosophy, October, 1949. (b) Present address: Department of Chemistry, Illinois Institute of Technology, Chicago, Illinois.

[2] Kirner and Richter, THIS JOURNAL, **51**, 3131 (1929).

[3] (a) Reichstein, *Ber.*, **63B**, 749 (1930); (b) Runde, Scott and Johnson, THIS JOURNAL, **52**, 1284 (1930).

[4] Scott and Johnson, *ibid.*, **54**, 2549 (1932).

[5] Campaigne and LeSuer, *ibid.*, **70**, 155 (1948).

[6] Ref. 9, p. 651, footnote 12; ref. 4, p. 2551, footnote 7.

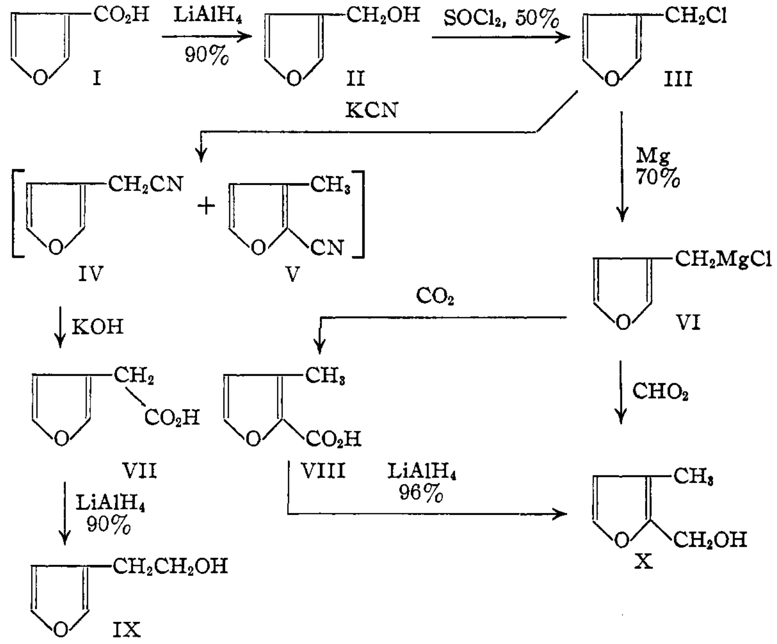
or benzyl iodide with sodium cyanide. Similarly, only the normal product was obtained when cinnamyl bromide was treated with potassium cyanide.[7]

Unfortunately all efforts to prepare a usable Grignard reagent from α-furfuryl chloride have been unsuccessful,[8] which limits the further comparison of α- and β-isomers in this series. On the other hand, Campaigne and LeSuer[5] have reported the formation of a Grignard reagent from 3-thenyl bromide which upon subsequent carbonation gave, in addition to the expected coupling product, *sym*-di-3-thienylethane, some 3-methyl-2-thienoic acid. After careful (microscopical) examination of all portions of the product from the reaction of carbon dioxide and benzylmagnesium chloride, Austin and Johnson[9] found that no allylic reaction product was formed; the normal product, phenylacetic acid, was obtained in fair yield. Carbonation of the Grignard reagent prepared from cinnamyl chloride resulted initially in phenylvinylacetic acid which was converted by heat to the more stable methylatropic acid.[10]

The reaction between 3-thenylmagnesium bromide and formaldehyde has not yet been investigated and so a comparison with the furan analog cannot be made at this time. It has not been reported[11] that, in addition to *sym*-diphenylethane, *o*-tolylcarbinol and not β-phenylethanol is obtained by the action of formaldehyde on benzylmagnesium chloride. In the case of the reaction between formaldehyde and the Grignard reagent from cinnamyl chloride, all that has been reported[10b] is that oxidation of the product gave benzoic acid but not phthalic or terephthalic acid. Hence ring participation is excluded.

Since this study required the preparation of relatively large quantities of 3-furoic acid for starting material, a procedure was needed which would give fairly good yields and which was relatively free of difficulties. Of the several available methods,[12] only the one due to Reichstein, *et al.*,[12c] met these requirements. Thus, after slight modifications necessary for large-scale work, 3-furoic acid was prepared in average over-all yields of approximately 47% (based on the bromine).[13]

The conversion of 3-furoic acid (I) to 3-furylcarbinol (II) by reduction with lithium aluminum hydride according to the general procedure of Nystrom and Brown[14] was accomplished in yields averaging 90% of the theoretical. A schematic representation of the preparation of 3-furylcarbinol (II) and of the compounds derived from it is given.



3-Furylcarbinol (II), a water-white liquid, is soluble in water and the common organic solvents. It is less susceptible to the action of mineral acids than its α-isomer as shown by a qualitative study of the rate of decomposition induced by dilute hydrochloric acid.

Adaptation of a modification of the Darzens procedure as reported by Reichstein[3a] served for the preparation of 3-furylmethyl chloride (III) from 3-furylcarbinol (II) in average yields of approximately 50%. Lower yields of chloride were obtained when the modification due to Kirner[15] was used, and when the compound was prepared in the absence of a base to take up the free acid, the yield was lower still.

3-Furylmethyl chloride (III) is not lachrymatory and is much more stable than the isomeric α-furfuryl chloride for, unlike the latter, it does not decompose when distilled in the presence of traces of mineral acid.

Treatment with strong aqueous potassium cya-

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[7] Borsche and Niemann, *Ber.*, **69**, 1993 (1936); p. 1996, footnote 7.

[8] Gilman and Hewlett, *Rec. trav. chim.*, [4] **51**, 93 (1932).

[9] Austin and Johnson, THIS JOURNAL, **54**, 647 (1932).

[10] (a) Gilman and Harris, *ibid.*, **49**, 1825 (1927); (b) **53**, 3541 (1931).

[11] Gilman and Kirby, *ibid.*, **54**, 345 (1932); Tiffeneau and Delange, *Compt. rend.*, **137**, 573 (1903); Grignard, *Bull. soc. chim.*, [3] **29**, 953 (1903).

[12] (a) Gilman and Burtner, THIS JOURNAL, **55**, 2903 (1933); (b) Reichstein and Zschokke, *Helv. Chim. Acta*, **15**, 268 (1932); (c) Reichstein, Grussner, Schindler and Hardmeier, *ibid.*, **16**, 276 (1933).

[13] The reaction sequence used was: diethyl sodium oxalacetate + bromine → tetraethyl "dioxalosuccinate" → tetraethyl furantetracarboxylate → furantetracarboxylic acid → 3-furoic acid (I).

[14] Nystrom and Brown, THIS JOURNAL, **69**, 2548 (1947).

[15] Kirner, *ibid.*, **50**, 1955 (1928).

nide converted the chloride to a mixture of 3-furylacetonitrile (IV) and 3-methyl-2-furonitrile (V) contaminated with isocyanides and some polymeric material. The nitriles were not completely separable by fractional distillation under reduced pressure and so the mixture was hydrolyzed directly to the corresponding acids. These were separated by fractional crystallization alternately from low-boiling petroleum ether and water, and were found present in the approximate ratio of 90% of 3-furylacetic acid (VII) to 10% of 3-methyl-2-furoic acid (VIII). The separation of 3-furylacetic acid (VII) from 3-methyl-2-furoic acid (VIII) was complicated by the instability of the former (like its α-isomer), especially when in the impure state. Once purified, 3-furylacetic acid (VII) is relatively stable and can be converted to the acid chloride in the usual manner.

That the isomeric product was 3-methyl-2-furoic acid (VIII) was shown in several ways. First, like all α-furoic acids, it was acidic to congo red indicator and gave an orange precipitate when treated with ferric chloride solution. In addition, it was converted to the known acid chloride and subsequently to the known methyl and ethyl esters, amide and anilide. Unequivocal confirmation was obtained[16] through a mixed melting point with a sample of pure 3-methyl-2-furoic acid (VIII).

For the studies on the Grignard reagent prepared from 3-furylmethyl chloride (III), 3-furylacetic acid (VII) and 3-methyl-2-furoic acid (VIII) were converted to the corresponding carbinols by reduction with lithium aluminum hydride. The yield in each instance exceeded 90% of the theoretical. β-3-Furylethanol (IX), a colorless liquid, soluble in water and the common organic solvents, appears to be as stable as its α-isomer.[17] 3-Methyl-2-furfuryl alcohol (X), also a colorless liquid, exhibits the same solubility behavior. Although it is sensitive to atmospheric oxygen, it can be stored in the absence of oxygen without noticeable decomposition.

When an ethereal solution of 3-furylmethyl chloride (III) was treated with magnesium, a Grignard reagent was formed to the extent of approximately 70% (as determined by titration). Carbonation of the Grignard reagent resulted in 33.5% yield of a mixture of crude acids consisting of approximately 10% of 3-furylacetic acid (VII) and 90% of 3-methyl-2-furoic acid (VIII). The reaction between formaldehyde and the Grignard reagent produced the result of allylic reaction, 3-methyl-2-furfuryl alcohol (X), in 33.4% yield. Confirmation of the structure of the latter was obtained by the mixed melting and decomposition point of its α-naphthylurethan with the derivative prepared from 3-methyl-2-furfuryl alcohol synthesized in an unambiguous manner. The similarity in boiling points and refractive indices served as further confirmatory evidence.

On the basis of our results and the data obtained from the literature, we propose the following as the relative order of the (decreasing) tendency toward formation of "abnormal" or allylic reaction products in the case of the halides in reaction with aqueous cyanide: α-furfuryl, β-furylmethyl, β-thenyl, cinnamyl, benzyl. (The position of the cinnamyl group is rather uncertain due to the nature of the data available.) The approximate order obtaining in the case of the Grignard reagents is: cinnamyl, β-furylmethyl, β-thenyl, benzyl.

The fact that β-furfuryl chloride produces a typically stable Grignard reagent whereas the α-isomer does not is attributable to the β-halogen ether structure of the latter. The absence of 3,4-disubstituted furans among the products of reaction indicates an effectively "fixed" double-bond structure in the ring. Likewise the large portion of 3-methyl-2-furoic acid obtained on carbonation (with benzyl Grignard a completely "normal" or non-allylic process) of the β-furfuryl Grignard reagent is interpreted as indicative of the olefinic properties of the ring double bonds. These effects are again ascribable to the ring oxygen and its restriction of aromatic resonance.

Acknowledgment.—The senior author is grateful to Dr. John R. Johnson for stimulating in him an interest in and a curiosity regarding the furan nucleus. To Dr. T. Reichstein the authors express their thanks for the mixed melting point determination.

Experimental[18]

3-Furoic Acid (I).—This naturally occuring compound[19] was prepared according to the method of Reichstein, *et al.*,[12c] but taking advantage of the fact that it was not necessary to isolate the intermediate decarboxylation products. A 250-ml. distilling flask provided with alembic was charged with an intimate mixture of 40 g. (0.164 mole) of finely ground furantetracarboxylic acid, 4 g. of copper powder and 50 ml. of crude coal tar base.[20] A gas inlet tube was inserted almost to the bottom of the flask and a cooled 250-ml. distilling flask was used as a receiver. The reaction flask was heated cautiously by alternately raising and lowering a metal-bath kept at about 285° while a steady stream of nitrogen was passed through to sweep out the acid as fast as it was formed. The mixture foamed considerably at the outset of the decarboxylation and was kept under control by playing a small flame at the surface of the mixture. When the vigorous frothing had subsided, it was found safe to have the bath fixed in position. The decarboxylation, which proceeded smoothly as the temperature of the bath was raised gradually to 325°, was interrupted when no more liquid was apparent in the reaction flask. The furoic acid was extracted with saturated sodium bicarbonate solution, decolorized and recovered by acidification in practically pure form, m. p. 120–121° (10.4–12.0 g. or 56.6–65.3%). Thorough extraction of the filtrate with ether yielded an additional 2.1–1.8 g. of less pure acid, m. p. 117–120°, making the total yield 67.9–75.1%. The acid was purified further by recrystallization from water (charcoal) using 10 ml. of fresh solvent per gram of compound. The recovery of pure 3-furoic acid, m. p. 121–122°, was 88–98%.

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[16] Reichstein, private communication.

[17] Amstutz and Plucker, THIS JOURNAL, **63**, 206 (1941).

[18] All melting points are uncorrected.

[19] (a) Togerson, *Proc. Chem. Soc.*, **28**, 188 (1912); *J. Chem. Soc.*, **101**, 1044 (1912); (b) Power and Salway, *Pharm. J.*, **90**, 550 (1913); *C. A.*, **7**, 2659 (1913).

[20] The fraction distilling at 145–220° (12 mm.) was used.

3-Furylcarbinol (II).—This new alcohol was prepared by an adaptation of the general method of reduction of carboxylic acids with lithium aluminum hydride.[14] Thus, when a solution of 33.6 g. (0.3 mole) of 3-furoic acid in 450 ml. of absolute ether was added dropwise to a solution of 15 g. (0.395 mole) of lithium aluminum hydride[21] in one liter of absolute ether and the product worked up in the prescribed manner using 200 ml. of 20% sodium hydroxide solution,[22] there was obtained 25.3–26.9 g. (86.2–91.5%) of 3-furylcarbinol, a colorless liquid, b. p. 54–55° (2 mm.), b. p. 79–80° (17 mm.); d^{20}_4 1.1391; $n^{20}\text{D}$ 1.4842; *MR*D (calcd.) 25.32, *MR*D (obsd.) 24.65.

Anal. Calcd. for $C_5H_6O_2$: C, 61.21; H, 6.17. Found: C, 61.06; H, 6.35.

The phenylurethan,[23] fine white needles, melted at 105.2–105.6° after recrystallization from aqueous ethanol.

Anal. Calcd. for $C_{12}H_{11}O_3N$: N, 6.45. Found: N, 6.42.

The α-naphthylurethan, fine white needles, melted at 118.4–118.7° after recrystallization from aqueous ethanol.

Anal. Calcd. for $C_{16}H_{13}O_3N$: N, 5.24. Found: N, 5.23.

3-Furylmethyl Chloride (III).—A 200-ml., three-necked, round-bottomed flask equipped with a stirrer, dropping funnel and thermometer in a loose stopper, and containing 19.6 g. (0.2 mole) of 3-furylcarbinol, 19.1 g. (0.24 mole) of anhydrous pyridine and 25 ml. of absolute ether was cooled in an ice–salt-bath. The stirrer was started and when the temperature fell to −10°, a solution of 26.2 g. (0.22 mole) of purified thionyl chloride in 15 ml. of pentane was added as rapidly as possible yet keeping the reaction temperature below 30°.

The addition was completed in about fifteen minutes and the product was worked up as described by Reichstein.[3a] After removal of the solvent, the residue was distilled under reduced pressure (nitrogen atmosphere) in a protected system[15] There was obtained 11.1–12.7 g. (47.7–54.5%) of 3-furylmethyl chloride, a water-white liquid, b. p. 42–43° (17 mm.), b. p. 51–52° (27 mm.); d^{20}_4 1.1855; $n^{20}\text{D}$ 1.4863; *MR*D (calcd.) 28.67, *MR*D (obsd.) 28.24.

Anal. Calcd. for C_5H_5OCl: Cl, 30.42. Found: Cl, 30.47.

3-Furylmethylisothiouronium picrate, fine mustard-colored needles, melted at 142–143° after two recrystallizations from aqueous ethanol.

Anal. Calcd. for $C_{12}H_{22}O_8N_5S$: N, 18.18. Found: N, 18.11.

3-Furylacetonitrile (IV) and 3-Methyl-2-furonitrile (V).—To a solution of 8 g. (0.12 mole) of 98% potassium cyanide in 10 ml. of water was added 9.0 g. (0.077 mole) of 3-furylmethyl chloride. The mixture was heated with stirring for two hours at 70°; potassium chloride separated and some polymeric material formed during this period. After cooling, the brown, oily, upper layer was separated and the aqueous layer extracted several times with ether. The extracts were added to the oil and the mixture was dried over anhydrous magnesium sulfate. After removal of the solvent the reddish-orange residue was distilled under reduced pressure in an atmosphere of nitrogen. The product (5.5 g., 67.2%) consisted of a mixture of 3-furylacetonitrile and 3-methyl-2-furonitrile contaminated with isocyanides and boiled at 50–60° (3 mm.), the main portion distilling at 58–59°.[24]

3-Furylacetic Acid (VII) and 3-Methyl-2-furoic Acid (VIII).—The mixed nitriles (5.5 g., 0.051 mole) were hydrolyzed by refluxing with 30 ml. of 20% solution of potassium hydroxide in aqueous methanol (1:1) until the evolution of ammonia ceased. After cooling, the solution was washed with ether, heated, treated with charcoal, chilled and filtered. The filtrate was acidified strongly with concentrated hydrochloric acid, chilled and extracted thoroughly with ether. Evaporation of the combined extracts which had been dried over anhydrous magnesium sulfate resulted in 5.5 g. (84.7%) of slightly colored material, m. p. 50–55°, having an odor somewhat like that of phenylacetic acid.

The mixture of crude acids was taken up in low-boiling petroleum ether, filtered and allowed to cool slowly. Fairly pure 3-furylacetic acid, translucent white plates, m. p. 60–62°, separated. The mother liquor was evaporated to dryness, taken up in hot water, treated with charcoal, filtered and allowed to cool slowly. Under these conditions crude 3-methyl-2-furoic acid, m. p. 129–132° separated.

The aqueous mother liquor was extracted with ether and the ether evaporated after drying with anhydrous magnesium sulfate. The process of crystallizing first from petroleum ether and then from water was repeated twice, yielding in each instance a crop of the respective acid.

All the crude 3-methyl-2-furoic acid was combined and recrystallized from water (charcoal). There was obtained 0.55 g. (10% of the crude acid mixture, 5.7% over-all yield based on 3-furylmethyl chloride) of pure acid, long white needles, m. p. 134–135°. A mixed melting point with the acid prepared by carbonation of 3-furylmethylmagnesium chloride showed no depression.

The impure 3-furylacetic acid was recrystallized from petroleum ether (b. p. 60–68°). Pure acid (3.8 g., 68% of the crude acid mixture, 38.7% of the theoretical based on 3-furylmethyl chloride) was obtained after a second recrystallization from the same solvent; lustrous plates, m. p. 61.9–62.2°.

Anal. Calcd. for $C_6H_6O_3$: C, 57.14; H, 4.80; neut. equiv., 126.1. Found: C, 57.16; H, 4.90; neut. equiv., 27.1.

Treatment of 1 g. (0.008 mole) of 3-furylacetic acid with 2 ml. of purified thionyl chloride converted it to the acid chloride, b. p. *ca.* 53° (3 mm.), in 54% yield.

The amide was prepared by adding a portion of the acid chloride to excess anhydrous ammonia in absolute ether. Recrystallized from benzene–petroleum ether (b. p. 60–68°), the amide, white feathery needles, melted at 114–115°.

Anal. Calcd. for $C_6H_7O_2N$: N, 11.20. Found: N, 11.31.

The anilide was prepared by adding a portion of the acid chloride to an excess of freshly distilled aniline in absolute ether. The anilide was crystallized from benzene–petroleum ether (b. p. 60–68°), slender white blades, melted at 122.6–123.2°.

Anal. Calcd. for $C_{12}H_{11}O_2N$: N, 6.96. Found: N, 6.97.

β-3-Furylethanol (IX).—This new compound was prepared from 3-furylacetic acid by reduction with lithium aluminum hydride. Thus when 3.15 g. (0.025 mole) of 3-furylacetic acid in 50 ml. of absolute ether was added to a solution of 1.5 g. (0.04 mole) of lithium aluminum hydride in 100 ml. of absolute ether and the reaction mixture worked up in the prescribed manner, there was obtained 2.7 g. (96.5%) of β-3-furylethanol as a clear colorless liquid, b. p. 64–65° (3 mm.), b. p. 89–90° (18 mm.); d^{20}_4 1.0941; $n^{20}\text{D}$ 1.4828; *MR*D (calcd.) 29.94, *MR*D (obsd.) 29.24.

Anal. Calcd. for $C_6H_8O_2$: C, 64.27; H, 7.19. Found: C, 63.98; H, 7.40.

The phenylurethan, stout white needles from petroleum ether (b. p. 60–68°), melted at 58.3–58.8°.

Anal. Calcd. for $C_{13}H_{13}O_3N$: N, 6.06. Found: N, 6.04.

The α-naphthylurethan, clusters of fine white needles from petroleum ether (b. p. 60–68°), melted at 85.2–85.9°.

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[21] Metal Hydrides, Inc.

[22] Nystrom and Brown, in a private communication, recommended this strength alkali in the reduction of 2-furoic acid.

[23] Unless otherwise stated, all derivatives were prepared by the methods described by Shriner and Fuson, "Identification of Organic Compounds," John Wiley and Sons, Inc., New York, N. Y., 3rd ed., 1948.

[24] 3-Methyl-2-furonitrile distils at 54.5–55° (12 mm.); Reichstein, Zschokke and Goerg, *Helv. Chim. Acta*, **14**, 1277 (1931).

Anal. Calcd. for $C_{17}H_{15}O_3N$: N, 4.98. Found: N, 5.01.

3-Methyl-2-furfuryl Alcohol (X).—This new alcohol was prepared in the same manner as β-3-furylethanol. When 2.96 g. (0.023 mole) of 3-methyl-2-furoic acid was reduced with 1.5 g. (0.04 mole) of lithium aluminum hydride and the product separated in the usual way, there was obtained 2.33 g. (90.3%) of 3-methylfurfuryl alcohol, a water-white liquid, b. p. 79–80° (3 mm.); d^{20}_4 1.0917; n^{20}_D 1.4871; *MR*D (calcd.) 29.94, *MR*D (obsd.) 29.54.

Anal. Calcd. for $C_6H_8O_2$: C, 64.27; H, 7.19. Found: C, 64.03; H, 7.44.

The α-naphthylurethan, clusters of white needles from benzene–petroleum ether (b. p. 60–68°), feathery white needles from petroleum ether (b. p. 90–100°), colored at 143°, softened at 148°, and melted at 151–153° with decomposition.

Anal. Calcd. for $C_{17}H_{15}O_3N$: N, 4.97. *Found*: N, 4.91.

3-Furylmethylmagnesium Chloride (VI).—A Grignard reagent was prepared from 13.5 g. (0.116 mole) of 3-furylmethyl chloride and 2.82 g. (0.116 gram atom) of magnesium in 125 ml. of dry ether in the usual manner. Titration[25] of an aliquot indicated the presence of 71% of Grignard reagent.

A. **Reaction with Carbon Dioxide.**—The Grignard reagent described above was poured onto about 300 g. of crushed solid carbon dioxide. The reaction product was hydrolyzed with cold 25% sulfuric acid and then worked up in the usual way. There was obtained 3.5 g. of crude, tan-colored 3-methyl-2-furoic acid, m. p. 125–131°. The mother liquor was extracted thoroughly with ether, the extracts combined and dried with anhydrous magnesium sulfate. On evaporation of the ether 1.4 g. of a slightly oily solid was obtained. Total yield of crude acid was 4.9 g. (33.5%).

After several recrystallizations from water there was obtained 3.9 g. (80% of the crude acid; 26.8% yield based on 3-furylmethyl chloride) of pure 3-methyl-2-furoic acid, m. p. 134–135°.[26] When mixed with an authentic specimen, the melting point showed no depression.[16]

Anal. Calcd. for $C_6H_6O_3$: C, 57.14; H, 4.80; neut. equiv., 126.1. Found: C, 57.06; H, 4.96; neut. equiv., 126.9.

The acid was converted to the acid chloride (m. p. 18.5–19.5°) in the customary manner from which the methyl (m. p. 35–36°) and ethyl (m. p. 46.5–47.5°) esters, amide (m. p. 89–90°) and anilide (m. p. 89.5–90.5°) were prepared according to the method given by Reichstein and co-workers,[24] and corresponded to the materials reported earlier.[24]

The aqueous mother liquors from the recrystallizations of the 3-methyl-2-furoic acid were combined and extracted with ether. The combined extracts were dried with anhydrous magnesium sulfate and then evaporated. The residue was taken up in low-boiling petroleum ether and allowed to cool slowly. The mother liquor was decanted from the needles of 3-methyl-2-furoic acid that had formed. On chilling, 0.25 g. (5% of the crude acid, 1.7% of the theoretical based on 3-furylmethyl chloride) of impure 3-furylacetic acid, m. p. 48–59°, was deposited. Slow recrystallization from low-boiling petroleum ether raised the melting point to 59–61°. When mixed with a specimen of pure 3-furylacetic acid, the melting point was 60–62°.

B. **Reactions with Formaldehyde.**—The Grignard reagent was prepared from 14.3 g. (0.123 mole) of 3-furylmethyl chloride and 3 g. (0.123 gram atom) of magnesium as described earlier. The reagent was treated with gaseous formaldehyde prepared by the depolymerization of 7.5 g. of paraformaldehyde.[27] A brown oil separated initially followed by a flocculent white precipitate. The reaction was complete at the end of two hours as was indicated by a negative test for the presence of Grignard reagent.[28]

The reaction product was hydrolyzed by the gradual addition of an ice-cold solution of 13 g. of ammonium chloride in 38 ml. of water. The ether layer was separated, washed with saturated sodium bicarbonate solution and dried with anhydrous magnesium sulfate. After removal of the solvent, the residue was distilled under reduced pressure in an atmosphere of nitrogen. There was obtained 4.6 g. (33.4% based on the chloride) of 3-methyl-2-furfuryl alcohol, b. p. 79–81° (3 mm.), n^{20}_D 1.4880.

The α-naphthylurethan melted at 151–153° (dec.) after recrystallization from petroleum ether (b. p. 90–100°), and showed no depression when mixed with an authentic specimen of the compound.

Summary

Several new mono-β-substituted furans have been synthesized and characterized. Among these are 3-furylcarbinol, 3-furylmethyl chloride, 3-furylacetic acid and β-3-furylethanol.

The reaction between 3-furylmethyl chloride and strong aqueous potassium cyanide resulted in the formation of a mixture of nitriles consisting of approximately 90% of 3-furylacetonitrile and 10% of 3-methyl-2-furonitrile.

A Grignard reagent has been prepared from 3-furylmethyl chloride in 71% yield. Carbonation of the reagent resulted in the formation of a mixture of acid in the approximate ratio of 90% of 3-methyl-2-furoic acid to 10% of 3-furylacetic acid (normal product). Treatment of the Grignard reagent with formaldehyde afforded only the product of allylic reaction, 3-methyl-2-furfuryl alcohol. The structure of the latter was proved by comparison of the alcohol and its derivative with authentic specimens synthesized in an unambiguous manner.

A comparison is made of the properties of the β-furfuryl compounds, the α-furfuryl isomers and where possible with the β-thenyl, benzyl and cinnamyl compounds.

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[25] Gilman, Zoellner and Dickey, THIS JOURNAL, **51**, 1576 (1929).

[26] Reported[26] melting point 136–137° (cor.).

[27] Gilman and Catlin, "Organic Syntheses," Coll. Vol. I, John Wiley and Sons, Inc., New York, N. Y., 2nd ed., 1949, p. 188.

[28] Gilman and Schulze, THIS JOURNAL, **47**, 2002 (1925).