The hexyloxy compound was oxidized[17] to the known 4-*n*-hexyloxybenzoic acid.[29]

β-(4-*n*-Hexylbenzoyl)-propionic Acid.—This compound was prepared in the same manner as the majority of the aroylacrylic acids. The compound was oxidized[17] to the known 4-*n*-hexylbenzoic acid.

Reaction Product of β-Benzoylacrylic Acid with Cysteine.—Three grams (0.017 mole) of β-benzoylacrylic acid was dissolved in 12 ml. of water and the solution adjusted to *p*H 7 with aqueous sodium hydroxide solution. A solution of 2.68 g. (0.017 mole) of cysteine hydrochloride in 12 ml. of water was treated with aqueous sodium hydroxide until the *p*H was 7. The solutions were mixed and allowed to stand overnight.

The mixture had become slightly yellow and the *p*H was 7.3. Dilute hydrochloric acid was added dropwise until *p*H 2 was reached. The white precipitate was filtered off, washed several times with water, then recrystallized from 60% ethanol solution.

Antibacterial Tests.—The compounds were tested as growth inhibitors of *Staphylococcus aureus*, *Escherichia coli* and *Klebsiella pneumoniae* in nutrient broth by the serial dilution method using as an inoculum, 1 ml. of a 1:1000 dilution of a twenty-four hour culture of the test organism and a final volume of 5 ml. in each tube. Incubation was for eighteen hours at 37°. Tests with *Clostridium perfringens* and *Mycobacterium tuberculosis* H37Rv were conducted as previously described.[10] To avoid fluctuations in susceptibility of the test organisms, all compounds of a series were tested against a single organism at the same time and benzoylacrylic acid was used as a reference test compound for series of tests conducted on different days.

Acknowledgment.—The authors wish to express their appreciation for the analytical determinations and the corrected melting points which were carried out under the direction of Mr. M. E. Auerbach in the Analytical Laboratories of this Institute. We are indebted to Dr. F. C. Nachod and his staff for the surface-tension measurements. We are appreciative also of the technical assistance given by Mrs. G. W. Schraver during the course of this investigation.

Summary

1. A number of substituted β-aroylacrylic acids were prepared and their antibacterial activity determined *in vitro*.

2. With the *n*-alkyl series there was a noticeable increase in activity against gram positive bacteria as the length of the alkyl chain was increased, the C_9 chain being approximately the optimum chain length. The antibacterial activity appears to result from the presence of the highly conjugated benzoylacryl- system which may react with biologically essential —SH groups; the lipophilic ring substituents quantitatively increase the activity against gram positive bacteria.

3. The following 4-*n*-alkylbenzoic acids are considered to be reported for the first time: *viz.*, *n*-nonyl, *n*-decyl and *n*-dodecyl.

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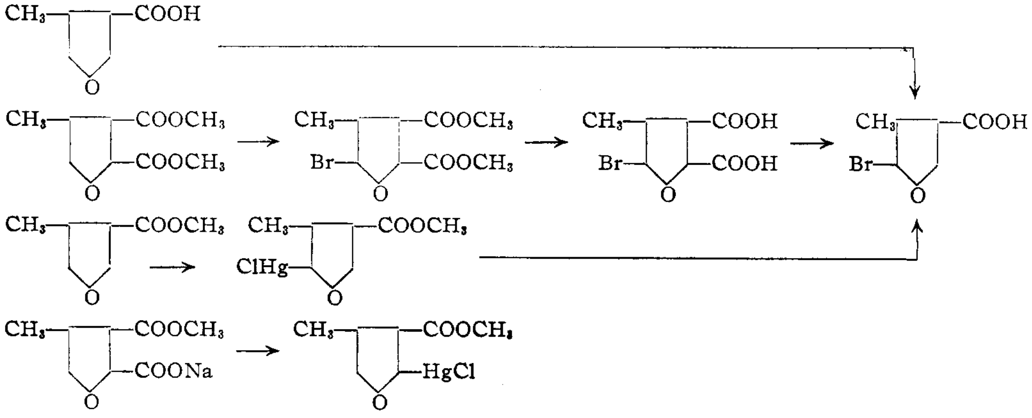
(29) Jones, *J. Chem. Soc.*, 1874 (1935).

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF IOWA STATE COLLEGE]

Orientation in the Furan Nucleus. XII. 3-Methyl-4-furoic Acid and Some of its Derivatives

BY HENRY GILMAN AND ROBERT R. BURTNER[1]

In a previous paper dealing with orientation of β-substituted furans[2] the prediction was made on the basis of evidence then available that nuclear substitution of 3-methyl-4-furoic acid would involve replacement of hydrogen on the 2-position. The validity of this assumption as regards bromination of the acid, mercuration of the methyl ester, and nitration of the ethyl ester has now been established by a sequence of reactions as shown.



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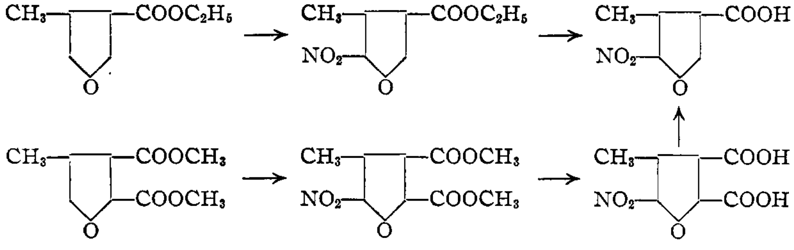
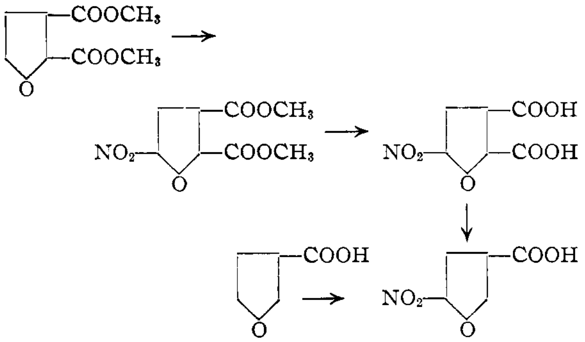
[1] Present address: G. D. Searle & Co., Chicago, Ill.

(2) Gilman and Burtner, THIS JOURNAL, **55**, 2903 (1933).



The above transformations are based on the nominal yields of products isolated from these somewhat sensitive compounds.

In addition, the position of the nitro group in 2-nitro-4-furoic acid[2] has been definitely established in the following manner



Experimental Part

2-Bromo-3-methyl-4-furoic acid.—Nine and six-tenths grams (0.06 mole) of bromine was added dropwise to a stirred solution of 6.3 g. (0.05 mole) of 3-methyl-4-furoic acid[3] in 40 ml. of acetic acid at 15–20°. The reaction mixture was then stirred for twelve hours at laboratory temperature, placed under reduced pressure for one hour to remove excess bromine and finally poured onto 250 g. of ice. The crude product was filtered, crystallized from hot water and sublimed in vacuum to yield 2 g. of the acid melting at 163–164°.

Anal. Calcd. for $C_6H_5O_3Br$: Br, 39.02. Found: Br, 39.11.

Methyl 2-Chloromercuri-3-methyl-4-furoate.—A solution of 2.5 g. (0.017 mole) of methyl 3-methyl-4-furoate in 10 ml. of ethanol was added to a solution of 4.6 g. (0.017 mole) of mercuric chloride and 2.88 g. (0.034 mole) of anhydrous sodium acetate in 100 ml. of water. The mixture was stirred for twelve hours, filtered to remove a flocculent white precipitate and the filtrate gently refluxed with stirring for four hours. Filtration of the cooled mixture yielded a second crop of the crude mercurial. Both fractions were combined and crystallized from ethanol to give 2 g. of the desired material, which melted at 175°.

Anal. Calcd. for $C_7H_7O_3ClHg$: Hg, 53.49. Found: Hg, 53.18.

Conversion of Methyl 2-Chloromercuri-3-methyl-4-furoate to 2-Bromo-3-methyl-4-furoic Acid.—One and two-tenths grams (0.0075 mole) of bromine was added to a stirred suspension of 1.8 g. (0.005 mole) of the mercurial in 15 ml. of acetic acid at laboratory temperature. There was a mild heat effect, and the mercurial dissolved. The solution was stirred for three hours, diluted with 400 ml. of water and the excess bromine reduced with sulfur dioxide. The mixture was then saturated with hydrogen sulfide, refluxed for one hour and filtered hot to remove the mercuric sulfide. Ether extraction of the cold filtrate yielded a yellow crystalline solid, which after crystallization from water melted at 161°. A mixed melting point determination proved this acid to be identical with that described above.

2-Bromo-3-methylfuran-4,5-dicarboxylic Acid.—Six and four-tenths grams (0.04 mole) of bromine was added dropwise at 20° to a stirred solution of 4.4 g. (0.022 mole) of dimethyl 3-methylfuran-4,5-dicarboxylate[3] in 25 ml. of chloroform. The mixture was stirred for three hours longer after which the solvent and excess bromine were removed under reduced pressure. The residual crystals, after being washed with a small amount of ether, melted at 131–132°. Saponification was effected by refluxing for three hours with an alcoholic solution of potassium hydroxide. Removal of the solvent followed by solution of the residue in water and acidification yielded 1.5 g. of a colorless acid melting at 257° with gas evolution.

Anal. Calcd. for $C_7H_5O_5Br$: Br, 32.13. Found: Br, 31.5.

Decarboxylation of 2-Bromo-3-methylfuran-4,5-dicarboxylic Acid.—A solution of 1.1 g. (0.004 mole) of the bromo acid, 1.2 g. (0.004 mole) of mercuric chloride and 0.25 g. of sodium hydroxide in 40 ml. of water was refluxed for one hour, by which time carbon dioxide evolution had ceased. The mixture was made alkaline to phenolphthalein with sodium hydroxide, filtered and the filtrate acidified. After dilution with water to a volume of 200 ml. and saturation with hydrogen sulfide the mixture was boiled briefly, filtered and the filtrate chilled. The product thus obtained was recrystallized from water to yield 0.3 g. of an acid which melted at 165°. A mixed melting point determination showed this acid to be identical with that obtained by direct bromination of 3-methyl-4-furoic acid.

3-Methyl-4-carbomethoxy-5-furoic Acid.—A solution of 12 g. (0.06 mole) of dimethyl 3-methylfuran-4,5-dicarboxylate and 3.4 g. (0.06 mole) of potassium hydroxide in 60 ml. of methanol was refluxed until it was no longer alkaline to phenolphthalein. After removal of the solvent under reduced pressure the residue was dissolved in 15 ml. of water, acidified and the crude product filtered. Crystallization from 50% ethanol and finally from benzene gave 8.5 g. of the desired product melting at 119.5°.

Anal. Calcd. for $C_8H_8O_5$: C, 55.10; H, 4.08; neut. equiv., 184. Found: C, 55.01; H, 4.36; neut. equiv., 182.7.

3-Methyl-4-carbomethoxy-5-chloromercurifuran.—Four grams (0.021 mole) of 3-methyl-4-carbomethoxy-5-furoic acid was dissolved in 40 ml. of water containing 0.84 g. (0.021 mole) of sodium hydroxide and added to a solution of 5.7 g. (0.021 mole) of mercuric chloride in 100 ml. of water. After standing for one and one-half hours the mixture was filtered and the filtrate refluxed with stirring for thirty minutes at which point carbon dioxide evolution had ceased. The precipitate, obtained by filtering the chilled reaction mixture, was extracted with boiling methanol for one and one-half hours. The chilled extract yielded a small amount of an unidentified white crystalline solid which decomposed at 235–240°. After a week's storage in the refrigerator the alcoholic filtrate was evaporated to yield a pale yellow crystalline material which upon recrystallization from methanol melted at 141–142°. A mixture of this mercurial with the isomeric 5-chloromercuri derivative melted at 122°.

Anal. Calcd. for $C_7H_7O_3ClHg$: Hg, 53.49. Found: Hg, 53.08.

2-Nitro-3-methyl-4-furoic Acid.—A solution of 9 g. (0.06 mole) of ethyl 3-methyl-4-furoate in 12 ml. of acetic anhydride was added dropwise with stirring at −10° to a nitrating mixture prepared in the customary manner from 18.9 g. (0.3 mole) of nitric acid (sp. gr. 1.51) and 30 ml. of acetic anhydride. The mixture was stirred for

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[3] Reichstein and Zschokke, *Helv. Chim. Acta*, **14**, 1270 (1931).

thirty minutes longer at −10° and then poured onto 150 g. of ice. The excess acid was carefully neutralized with 40% sodium hydroxide and the mixture extracted with ether. The extract was immediately treated with 20 ml. of pyridine and allowed to stand for twelve hours in the refrigerator. Removal of the solvent and acidification of the residue with an excess of ice cold 10% hydrochloric acid gave the crude ester, which after crystallization from methanol, weighed 5 g. and melted at 42°.

Anal. Calcd. for $C_8H_9O_5N$: C, 48.24; H, 4.52. Found: C, 48.15; H, 4.71.

The ester was hydrolyzed by refluxing for two hours with a solution of 10 g. of sulfuric acid and 25 ml. of water. The acid melted at 194° after crystallization from water.

Anal. Calcd. for $C_6H_5O_5N$: C, 42.10; H, 2.92. Found: C, 41.93; H, 3.08.

This acid may also be obtained by direct nitration of 3-methyl-4-furoic acid. Twelve and one-half grams of the acid was added portionwise at −15° to a stirred nitrating mixture prepared from 36.6 g. of nitric acid (sp. gr. 1.51) and 78 ml. of acetic anhydride. The mixture was stirred for one hour longer at −10°, poured onto 500 g. of ice and extracted with ether. The solvent was evaporated and the crude product crystallized from water to give 4.2 g. of the acid melting at 193°.

2-Nitro-3-methylfuran-4,5-dicarboxylic Acid.—Five grams of dimethyl 3-methylfuran-4,5-dicarboxylate was added in small portions with stirring at −10° to a nitrating mixture composed of 7.9 g. of nitric acid (sp. gr. 1.51) and 12 ml. of acetic anhydride. Stirring was continued for one hour at −10°, followed by dilution with ice, extraction and treatment with pyridine as previously described. The crude nitro ester was hydrolyzed by refluxing for seven hours with a solution of 10 g. of sulfuric acid and 25 ml. of water. After treatment with decolorizing charcoal the hot filtrate was chilled to give the crude acid. Crystallization from benzene yielded 1.5 g. of the acid melting at 218°.

Anal. Calcd. for $C_7H_5O_7N$: C, 38.88; H, 2.31; neut. equiv., 108. Found: C, 38.78; H, 2.81; neut. equiv., 107.3.

Decarboxylation of 2-Nitro-3-methylfuran-4,5-dicarboxylic Acid.—One-tenth gram of the dicarboxylic acid contained in a long, narrow test-tube was heated in a metal-bath at 225°. Carbon dioxide was evolved, and a white crystalline solid condensed on the upper walls of the tube. This material melted at 194° and showed no depression in melting point when mixed with samples of 2-nitro-3-methyl-4-furoic acid previously described.

Dimethyl 2-Nitrofuran-4,5-dicarboxylate.—A solution of 6.2 g. (0.033 mole) of dimethyl furan-2,3-dicarboxylate[4] in 9 ml. of acetic anhydride was added dropwise at −10° to a stirred nitrating mixture prepared from 10.3 g. (0.16 mole) of nitric acid (sp. gr. 1.51) and 15.6 ml. of acetic anhydride. The mixture was stirred for an additional hour at −10°, poured onto ice, neutralized with caustic solution, extracted with ether and the extract treated with 20 ml. of pyridine. After twelve hours of storage in the refrigerator the solvent was removed and the residue suspended in an excess of ice-cold 10% hydrochloric acid. The crude product thus obtained was crystallized from methanol to give 5.1 g. of the nitro ester melting at 97°.

Anal. Calcd. for $C_8H_7O_7N$: C, 41.92; H, 3.05. Found: C, 42.15; H, 3.79.

Decarboxylation of 2-Nitrofuran-4,5-dicarboxylic Acid.—Four grams of the above ester was hydrolyzed by refluxing for four hours with a solution of 12 g. of sulfuric acid and 24 ml. of water. The chilled hydrolysate was washed once with chloroform to remove any unchanged ester and then extracted thoroughly with ether. Evaporation of the solvent yielded the crude 2-nitrofuran-4,5-dicarboxylic acid, which after crystallization from a mixture of ether and benzene melted at about 225° with gas evolution.

This material contained in a long, narrow test-tube was heated in a metal-bath at 235°. Carbon dioxide was evolved and a white crystalline solid deposited on the upper part of the tube. Resublimation followed by crystallization from water afforded an acid melting at 137°, which was identical with that obtained by the direct nitration of 3-furoic acid.[2]

Summary

Bromination of 3-methyl-4-furoic acid, mercuration of the methyl ester, and nitration of the ethyl ester result in substitution in the 2-position. The structure of 2-nitro-4-furoic acid has been established.

[4] Asahina, *et al.*, *Acta Phytochim.*, **2**, 1 (1924).

AMES, IOWA RECEIVED OCTOBER 11, 1948

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY AND CHEMICAL ENGINEERING OF THE UNIVERSITY OF PENNSYLVANIA]

The Ultraviolet Absorption Spectra of Aliphatic Sulfides and Polysulfides[1]

JOHN E. BAER[2] AND MARVIN CARMACK

Various organic polysulfides, RS_xR', have been prepared in which R and R′ are simple alkyl groups.[3] Recently interest has been aroused in the 2-chloroethyl polysulfides in connection with the characterization of the by-products of the manufacture of mustard gas by the Levinstein process.[4,5] Other aliphatic polysulfides of particular interest are the Thiokol types of elastomers and possible intermediates in the vulcanization of rubber.

In view of the differing opinions regarding the manner of attachment of the sulfur atoms in the organic polysulfides, new methods for the recognition of different types of linkages are of interest, particularly methods which do not alter the polysulfide groups chemically.

We have found that aliphatic polysulfides have intense and characteristic ultraviolet absorption

[1] The essential material of this paper was presented before the Organic Division of the American Chemical Society at the National Meeting in Chicago, Illinois, April 22, 1948. It is from the Ph.D. dissertation of John E. Baer, accepted by the Faculty of the Graduate School of Arts and Sciences of the University of Pennsylvania, June, 1948.

[2] Abbott Laboratories Fellow, 1946–1947. Present address: Department of Chemistry, Carleton College, Northfield, Minnesota.

[3] R. Connor, "Organic Chemistry," (ed. H. Gilman), John Wiley and Sons, New York, N. Y., ed. 2, 1943, Vol. I, p. 864.

[4] Fuson, Price, Burness, Foster, Hatchard and Lipscomb, *J. Org. Chem.*, **11**, 487 (1946).

[5] Macy, Jarman, Morrison and Reid, *Science*, **106**, 355 (1947).