

with boiling copper sulfate; yield 0.1 g.; m. p. 148–149°. All attempts to raise this yield by a variation of conditions failed.

Anal. Calcd. for $C_9H_9O_5N$: C, 51.18; H, 4.26. Found: C, 51.24; H, 4.00.

Summary

1. Nine negatively substituted phenols in the

veratrole and methylenedioxybenzene series have been prepared.

2. A measure of the relative acidities of these compounds strongly indicates that the benzenoid rings in the two series are very comparable in structure.

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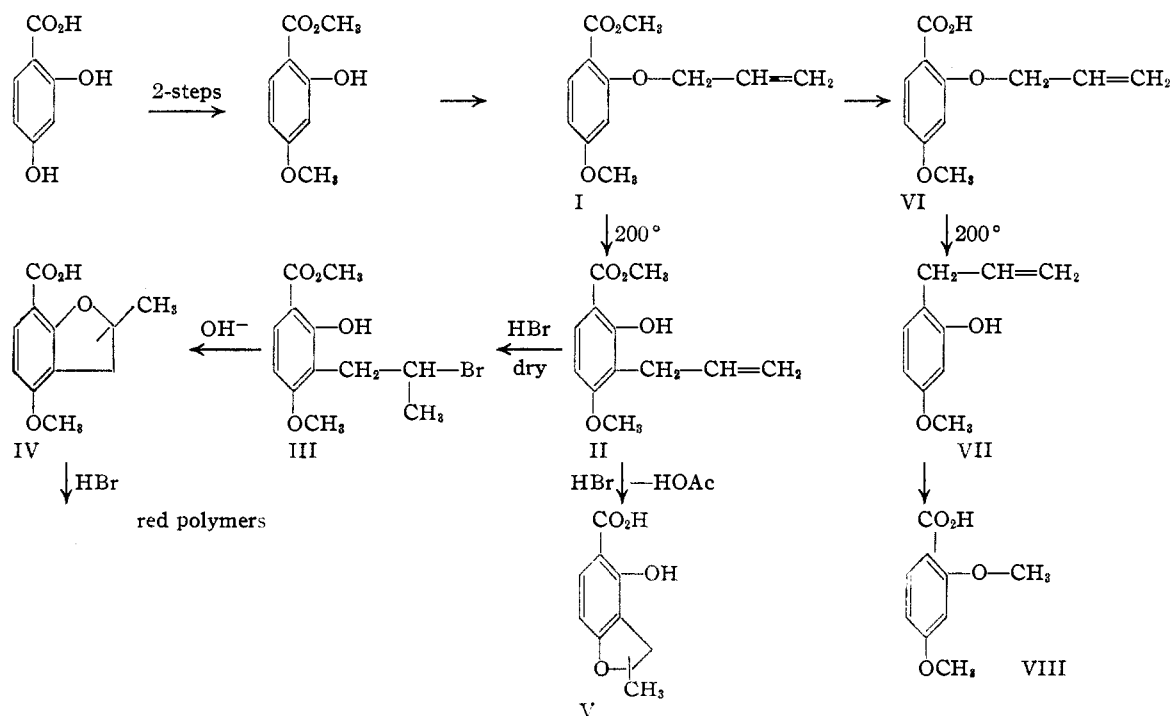
[CONTRIBUTION FROM THE SCHOOL OF CHEMISTRY OF THE UNIVERSITY OF MINNESOTA]

Studies in the Coumaran Series

BY RICHARD T. ARNOLD AND JOHN MORAN

In an attempt to ascertain whether or not the coumaran heterocyclic ring is partially cleaved to an opened chain intermediate in the presence of reagents which split ordinary ethers, we have prepared 2-methyl-4-methoxy-7-carboxycoumaran IV and subjected this molecule to treatment with concentrated solutions of hydrobromic acid.

Unfortunately no successful conditions were found for effecting this transformation directly. All experiments dealing with the cleavage of IV gave unidentifiable red polymers.^{1,2} We wish to describe, however, a number of syntheses carried out during the course of this investigation. These can be summarized as follows



If during the cleavage of the methoxyl group the cyclic ether does form an opened chain derivative, it is to be expected that recyclization would involve the hydroxyl group para to the carboxyl group rather than that in the ortho position since the latter is rather firmly held in a chelate ring structure.

Substitution studies have repeatedly shown that the resorcinol nucleus is preferentially attacked at that position ortho to one hydroxyl group and para to the other. The thermal rearrangement of monoallylresorcinol³ leads to the 1,2,4 configura-

(1) Schales, *Ber.*, **70**, 116 (1937).

(2) Niederl and Storch, *THIS JOURNAL*, **55**, 4549 (1933).

(3) Hurd, Greengard and Pilgrim, *ibid.*, **52**, 1700 (1930).

tion. In this respect it is of interest that compound VI rearranges completely with decarboxylation to give 2-hydroxy-4-methoxyallylbenzene.⁴ It may well be that decarboxylation precedes the rearrangement. The fact must not be overlooked, however, that below 160° the acid VI appears to be perfectly stable and above this temperature the carboxyl group may be eliminated through substitution by the allyl fragment.

When treated with hydrobromic acid, compound II did not cyclize easily but first underwent an ether cleavage followed then by ring closure to give a coumaran *o*-hydroxy acid (V). The relative position of the hydroxyl and carboxyl groups in V was established by the fact that the phenolic hydroxyl group was not attacked by diazomethane in twenty-four hours.^{5,6,7}

Compound II reacted readily with anhydrous hydrogen bromide in the presence of catalytic amounts of ferric chloride to give a solid addition product (III) which in turn was converted to a methoxycoumaran acid IV when treated with alkali.⁸

Experimental

Methyl 2-Hydroxy-4-methoxybenzoate.—Seventy grams of 2-hydroxy-4-methoxybenzoic acid was dissolved in 140 cc. of methanol and to this was added a cooled solution of 16 cc. of sulfuric acid in 16 cc. of methanol. The mixture was refluxed for forty-eight hours. Crystals of ester separated when the solution was cooled but were not filtered. An excess of cold water was added and the whole was extracted with ether. Bicarbonate extraction of the ether layer yielded 2 g. of the starting acid. Removal of the ether and crystallization from ether-petroleum ether gave 62 g. of the ester; m. p. 49–51°.⁹

Methyl 2-Allyloxy-4-methoxybenzoate (I).—Sixty grams of methyl 2-hydroxy-4-methoxybenzoate was dissolved in 500 cc. of anhydrous acetone and treated with 46 g. of potassium carbonate, 50.5 g. of allyl chloride, and 25 g. of sodium iodide. The solution was refluxed while being efficiently stirred for fifty-two hours. The cooled solution was filtered and the bulk of the acetone was separated from the filtrate by distillation on a steam cone. The residue was taken up in ether and successively extracted with water, sodium hydroxide solution (5%), and a solution of sodium thiosulfate. The resulting ether layer was dried with sodium sulfate and warmed on a water-bath to remove the ether. Recrystallization of the residue from petroleum ether gave 49 g. of the expected product which gave no color reaction with ferric chloride; m. p. 49–50°.

Anal. Calcd. for C₁₂H₁₄O₄: C, 64.85; H, 6.35. Found: C, 64.90; H, 6.20.

(4) Tarbell, *Chem. Rev.*, **27**, 529 (1940).

(5) Herzig and Tichatschel, *Ber.*, **39**, 1558 (1906).

(6) Spath and Jeschki, *ibid.*, **57**, 471 (1924).

(7) Homeyer and Wallingford, *THIS JOURNAL*, **64**, 798 (1942).

(8) Stoermer, *Ber.*, **34**, 1810 (1901).

(9) Hersig and Wenzel, *Monatsh.*, **24**, 887 (1903).

Methyl 2-Hydroxy-3-allyl-4-methoxybenzoate (II).—Fifty grams of I was dissolved in 130 cc. of redistilled N,N-dimethylaniline and placed in a 200-cc. flask to which an air condenser was attached. The solution was refluxed in a nitrogen atmosphere for six hours. During this time the solution darkened but little. The dimethylaniline was largely removed by vacuum distillation. The residue was dissolved in ether and extracted with dilute hydrochloric acid. The dried ether solution was evaporated on a steam cone, and when cooled in a salt-ice bath the residue crystallized. Recrystallization from methanol solutions gave 34 g. of product melting at 57–59°. This substance gave a red-violet color with alcoholic ferric chloride.

Anal. Calcd. for C₁₂H₁₄O₄: C, 64.85; H, 6.35. Found: C, 64.70; H, 6.59.

Hydrobromic Acid Treatment of Compound II.—Ten and one-half grams of methyl 2-hydroxy-3-allyl-4-methoxybenzoate was dissolved in 40 cc. of glacial acetic acid and treated with 13 cc. of hydrobromic acid (40%). The mixture was warmed on a steam-bath for twelve hours then poured into cold water. The residue was completely saponified by refluxing with 50 cc. of sodium hydroxide solution (10%). The hot solution was partially decolorized with charcoal, filtered, cooled, and acidified. A crude mixture of acids melting at 150–190° was obtained and separated by fractional crystallization into two pure components m. p. 155–156° and m. p. 203–205°. The lower melting compound was assigned formula V. It gave a positive (red) color test with ferric chloride. In the presence of a four-fold excess of diazomethane a methyl ester was obtained which liberated the hydroxy acid on basic hydrolysis.

Anal. Calcd. for C₁₀H₁₀O₄: C, 61.83; H, 5.19. Found: C, 61.63; H, 5.06.

The high melting compound (203–205°) was assigned formula IV and was obtained in a more pure condition as described below.

Methyl 2-Hydroxy-3-(β-bromo-*n*-propyl)-4-methoxybenzoate.—Eight grams of compound II was dissolved in 20 cc. of anhydrous chloroform, cooled to 0° and treated with a few milligrams of black anhydrous ferric chloride. Dry hydrogen bromide was passed through the solution for thirty minutes and the solution was allowed to stand at room temperature for twenty-seven hours. The solvent was removed under diminished pressure and the residue immediately crystallized. When treated with ether, one gram of the residue remained undissolved and was filtered. After recrystallization from benzene-ethanol, it melted at 207–208° and proved to be a pure sample of the compound (IV) reported above as melting at 203–204°.

Anal. Calcd. for C₁₁H₁₂O₄: C, 63.40; H, 5.81. Found: C, 63.13; H, 5.96.

The ether solution was evaporated and 5 g. of a bromo derivative (III) was obtained after recrystallization from petroleum ether; m. p. 73–74°.

Anal. Calcd. for C₁₂H₁₆O₄Br: C, 47.54; H, 4.99. Found: C, 47.82; H, 5.50.

2-Methyl-4-methoxy-7-carboxycoumaran.—Five grams of the bromo compound (III) was shaken with 20 cc. of sodium hydroxide for fifteen minutes and was refluxed for an additional fifteen minute interval. The resultant solu-

tion was cooled, filtered, and carefully acidified. The precipitate was recrystallized from benzene-ethanol and melted at 207–208°. Mixed melting point determinations showed this substance to be identical with samples obtained in earlier experiments as described above.

2-Hydroxy-4-methoxyallylbenzene.—One and three-tenths grams of 2-allyloxy-4-methoxybenzoic acid dissolved in 12 cc. of *N,N*-dimethylaniline was refluxed for six hours, cooled, and poured into ether. The amine was removed from the ether layer by extraction with hydrochloric acid. Evaporation of the ether gave an oil which was soluble in

sodium hydroxide and completely insoluble in sodium bicarbonate. A positive ferric chloride test was obtained. The structure of this oil was established by methylation, isomerization with alkali, and oxidation to 2,4-dimethoxybenzoic acid; m. p. and mixed m. p. 108°.

Summary

A number of reactions leading to the formation of substituted coumarans have been described.

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Solvent Polarization Error and its Elimination in Calculating Dipole Moments

BY I. F. HALVERSTADT^{1,2} AND W. D. KUMLER

An old idea in dipole moment literature is that $P_{12}-N_2$ (or $p_{12}-\omega_2$) curves would be straight lines in the absence of intermolecular action³ or molecular association. This idea is implicit in the usual methods of calculating the degree of molecu-

lar association from polarization concentration curves, and in the calculation of dipole moments by a linear extrapolation of P_2-N_2 curves, a method still used by a number of authors.

Considerable evidence has accumulated which indicates that the dielectric constant ϵ_{12} is a linear function of the weight fraction of solute ω_2 ^{4,5,6,7} in dilute solutions.

We have examined over fifty compounds of widely different nature and have found ϵ_{12} to be linear with ω_2 in every case as long as ω_2 is less than 0.01. Now it can be shown from the nature of the relation

$$p_{12} = \frac{\epsilon_{12} - 1}{\epsilon_{12} + 2} \frac{1}{d_{12}}$$

that if ϵ_{12} is linear with respect to ω_2 , p_{12} is not linear with ω_2 . The extent of this deviation is shown in Fig. 1. The corresponding $p_2-\omega_2$ curves are given in Fig. 2 and it is to be observed that the latter curves are neither horizontal nor straight. It is thus obvious that a linear extrapolation of $p_2-\omega_2$ or P_2-N_2 curves introduces an error which is small in case of compounds with a low dipole moment and comparatively larger with compounds of high dipole moment.

This error is eliminated by the method of extrapolation proposed by Hedestrand.⁸ However, serious errors may result even with the use of Hedestrand's method if it is not realized that the dielectric constant of the solvent in the solution sometimes differs considerably from the measured dielectric constant of the pure solvent.

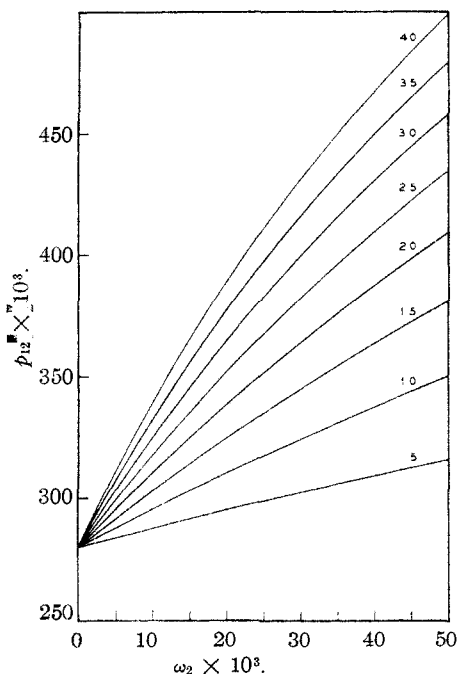


Fig. 1.—Theoretical polarization-concentration curves calculated by use of the Debye-Clausius-Mosotti equation for solutions in which ϵ_{12} is taken as linear with ω_2 (absence of association). β is taken in all cases as -0.2 and α has been varied from 5 to 40.

(1) Abraham Rosenberg Fellow in Pharmaceutical Chemistry, 1941–1942.

(2) Present address: American Cyanamid Company, Stamford, Conn.

(3) Smyth, "Dielectric Constant and Molecular Structure," Chemical Catalog Co., New York, N. Y., 1931, p. 176.

(4) Muller, *Physik. Z.*, **35**, 346 (1934).

(5) Rodebush and Eddy, *J. Chem. Phys.*, **8**, 424 (1940).

(6) McCusker and Curran, *This Journal*, **64**, 614 (1942).

(7) Wyman, *ibid.*, **58**, 1482 (1936).

(8) Hedestrand, *Z. physik. Chem.*, **B2**, 428 (1929).