

oxidants, give positive tests with trisubstituted silanes. Further differentiations are also possible if the time for color change is observed as well as the final color attained.

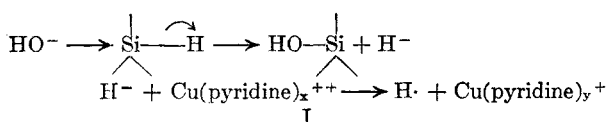
As could be predicted from the previously mentioned kinetic studies,^{6,7} there is a slight substituent effect on the rate of reaction. In the tables, the times recorded are for the specific compounds mentioned. However, time variations due to the substituent effect are small when compared with the variations due to degree of substitution at the silicon atom itself and this factor does not, therefore, reduce the applicability of the test. This was demonstrated more precisely when, after testing a total of seventy-two silanes containing either one, two or three hydrogen atoms attached to silicon, all were found to conform to the specifications of this test.¹²

In Table I are listed the various oxidants tested as possible indicators. In addition to those shown, copper(II) sulfate, vanadium(IV) sulfate, nickel(II) sulfate, iron(III) chloride, sodium chromate, chromium(VI) oxide, chromium(III) chloride, and cobalt(II) chloride were also investigated. The first three, all sulfates, and the iron(III) chloride gave precipitates in pyridine which obscured the color changes. The other four compounds underwent little or no color change over the three-minute period.

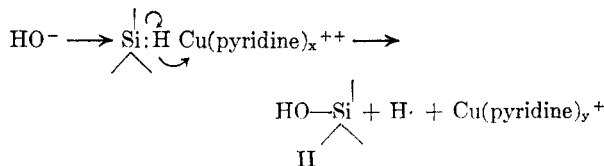
Other polar solvents were investigated as well, and the results, using copper(II) chloride as the oxidant, are assembled in Table II. All are capable of complexing the copper(II) ion somewhat, as evidenced by the various colors observed. It appears that a solvent of basicity and polarity close to that of pyridine is necessary. Piperidine, with its high basicity, is too reactive to be selective; while tetrahydrofuran, ethylene glycol dimethyl ether, and dioxane are not basic and/or polar enough. For intensity of original color and sharpness of color changes, none was as good as pyridine.

Completely nonaqueous systems were investigated also. Suspensions of chloranil, quinone, and azobenzene in pyridine underwent no reaction when treated with the various silanes. However, upon the addition of two drops of water, the evolution of hydrogen was observed and the colors of the solutions were slowly discharged.

These results indicate that hydroxide ion attack on the silane is the first step of the reaction, and the resultant reduction of the oxidant is either by hydride ion in a two step reaction (I) or by a concurrent one electron transfer (II). No attempt



(12) Some correlations between infrared spectra and the number of hydrogens attached to a silicon atom in organosilanes will be reported later



was made to ascertain which mode of reduction is actually followed.

EXPERIMENTAL

Oxidant solutions. Approximately 5% by weight solutions of all salts were prepared by dissolving 0.5 g. of the hydrated salt in 9.5 ml. of distilled water.

Solvents. All the solvents used were distilled and dried over sodium metal before use, except the pyridine and piperidine. The pyridine employed was a fresh bottle of Baker and Adamson purified grade and the piperidine was Eastman White Label.

Silanes. The times recorded in Tables I and II are for the silanes indicated. In the experiments involving pyridine, the triphenylsilane was added as a 50% by weight solution in pyridine. For the reactions involving other solvents a 50% solution of triphenylsilane in benzene was used for convenience.

Procedure. To one milliliter of the organic solvent was added 2 drops of the oxidant solution and the mixture was shaken until the color became uniform. One drop of the silane or silane solution was then introduced with shaking after which the reaction mixture was allowed to stand while the color changes were observed. The results are summarized in Tables I and II.

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o-(2,4-Dihydroxybenzhydryl)benzyl Alcohol

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Since *o*-(4,4'-dihydroxybenzhydryl)benzyl alcohol, which Baeyer called phenolphthalol, was found to be a good laxative,¹ it was decided to prepare and test its isomer, the *o*-(2,4-dihydroxybenzhydryl)benzyl alcohol (VI).

The starting material for its synthesis, the 3-phenyl-3-(2,4-dihydroxyphenyl)phthalide (I) has already been described, but neither of the two methods of preparation is satisfactory. Pech-

(1) M. H. Hubacher, S. Doernberg, and A. Horner, *J. Am. Pharm. Assoc.*, **42**, 23 (1953); O. E. Schultz and L. Geller, *Arch. Pharm.*, **287/59**, 584 (1954); **288/60**, 239 and 244 (1955).

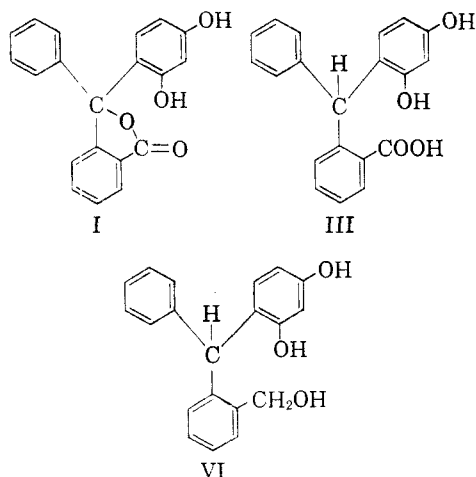
mann's² I has a very low melting point and shows color reactions which the pure I does not exhibit. Baeyer's³ procedure lacks important details, thus giving low yields and erratic results. The procedure described here gives consistent and good yields of pure I.

A second compound (II) melting at 290° is always formed along with I in the reaction between resorcinol and *o*-benzoylbenzoic acid. So far, our investigation has shown that II is not the anhydride of I, as Pechmann² thought. This interesting compound is now being investigated further.

The reduction of I leads to the *o*-(2,4-dihydroxybenzhydryl)benzoic acid (III), briefly mentioned by Pechmann.² Derivatives of this acid were prepared. One which forms by the elimination of one mole of water on heating of III, is most likely the ϵ -lactone of the α -(2,4-dihydroxyphenyl)- α -(phenyl)-*o*-toluic acid (V), reconverting to III on hydrolysis. This lactone also forms a monoacetyl derivative (Va) and a monomethyl ether (Vb). The latter forms an oily acid on hydrolysis which, on heating to 200°, again yields the monomethylether Vb. Dr. B. Katlavsky of Monsanto Chemical Co., who studied the infrared spectrum of V, reported that V could possibly be a lactone but that the infrared evidence could not in itself confirm or deny this possibility.

The formation of ϵ -lactones from similarly constituted compounds, such as from 2-carboxy-2'-hydroxydiphenylmethane, has been described by Baker, *et al.*⁴

The *o*-(2,4-dihydroxybenzhydryl)benzyl alcohol (VI) obtained by LiAlH₄ reduction of III, was found to possess distinct laxative properties. The pharmacological tests will be described elsewhere.



EXPERIMENTAL⁵

3-Phenyl-3-(2,4-dihydroxyphenyl)phthalide (I). Attempts to obtain I free from the by-product II, by changing the type

(2) H. v. Pechmann, *Ber.*, **14**, 1860 (1881).

(3) A. Baeyer, *Ann.*, **372**, 91 (1910).

(4) W. Baker, D. Clark, W. D. Ollis, and T. S. Zeally, *J. Chem. Soc.*, 1452 (1952).

of condensing agent, temperature, etc., were unsuccessful. In the absence of a condensing agent, no reaction takes place. Purification of the crude I by precipitation from its alkaline solution by carbon dioxide gives lower yields because it is not as stable in alkaline solution as are most other phthaloids.

A mixture of 22.0 g. (0.2 mole) of resorcinol, 45.2 g. (0.2 mole) of *o*-benzoylbenzoic acid, and 5.0 g. anhydrous zinc chloride was stirred for 2.5 hr. at 120°. Ethanol (150 ml.) was added to the hot, sticky, orange colored reaction mass and refluxed until it had dissolved. The solution, containing some white suspended II, was poured into 1200 ml. slightly acidic water. The precipitated pliable mass was treated with boiling water, hardening slowly on cooling: 53.5–62.3 g. (m.p. 130–148°) of a gray powder was obtained.

This crude I was refluxed with 1600 ml. absolute ether. The insoluble part was II (9.8–15.4 g; m.p. 276–285°). Crystals formed when the ethereal filtrate was evaporated to a volume of 200 ml. These were found to contain one mole solvate ether which was easily lost at 100°.

Anal. Calcd. for C₂₀H₁₄O₄·(C₂H₅)₂O: Ether, 18.9%. Found, loss in weight: 19.2 ± 0.5%.

Additional crystals were obtained by partial evaporation of the filtrate. The total yield of I, dried at 120°, was 30.5–39.0 g., m.p. 195–199° (48–61%). Sometimes, when no crystals are forming, the solvent is evaporated, leaving a gummy residue. On refluxing with chloroform, this residue first dissolves and then crystals containing one mole of chloroform form. These are the solvate crystals described by Baeyer.³

Pure 3-phenyl-3-(2,4-dihydroxyphenyl)phthalide (I) melts at 199.0–200.0° (Pechmann² 175–176° and Baeyer³ 198–199°).

Anal. Calcd. for C₂₀H₁₄O₄: C, 75.46; H, 4.47; mol. wt. 318. Found: C, 75.34; H, 4.36; mol. wt. 315.

I is very soluble in acetone and ethanol; soluble in absolute ether, but soon crystals containing solvate ether will form in such a solution.

A 0.001-molar solution of I in 0.1N sodium hydroxide is of strong reddish orange color⁶ which fades slowly when such a solution is exposed to the air, becoming yellow after one week.

A solution of 10 g. of I in 100 ml. N sodium hydroxide, heated for 30 min. to 100°, yielded 4.3 g. *o*-benzoylbenzoic acid and 2.2 g. resorcinol. When 5.0 g. of I was stirred in 50 g. molten KOH at 220° for 5 min., benzoic acid and some 2,4-dihydroxybenzophenone were obtained.

The deep orange solution of 0.1 g. of I in 5 ml. concd. sulfuric acid, when heated for 10 min. to 100°, yielded 0.042 g. anthraquinone.

When I was subjected to the oxime splitting of Friedlaender,⁷ a small quantity of a compound was obtained, which crystallized from ethanol in needles melting at 163.0–163.5°.

Anal. Calcd. for C₁₄H₉O₂N: C, 74.88; H, 4.04; N, 6.27; mol. wt. 223. Found: C, 75.24; H, 3.88; N, 6.85; mol. wt. 228.

A mixture of this compound with 4-phenyl-1*H*-2,3-benzoxazin-1-one (m.p. 162.5–163.0°) prepared by the method of Thorp⁸ melted at 162.7–163.1°.

Diacetyl derivative of I. Purified by crystallizations from ethanol, it melted at 141.0–141.9° (v. Pechmann 137°).

Anal. Calcd. for C₂₄H₁₈O₆: C, 71.63; H, 4.50; —COCH₃, 21.40. Found: C, 71.60; H, 4.55; —COCH₃, 21.27.

(5) All melting points are corrected. Molecular weights were determined by the Signer method as described by E. P. Clark, *Ind. Eng. Chem., Anal. Ed.*, **13**, 820 (1941).

(6) Color designation according to the Munsell Color System *Method of Designating Colors*, National Bureau of Standard Research Paper PR 1239, September 1939.

(7) M. H. Hubacher, *J. Am. Chem. Soc.*, **68**, 718 (1946).

(8) F. H. Thorp, *Ber.*, **26**, 1262, 1795 (1893).

Dimethylether of I. Prepared by heating 3.18 g. of I, 3.8 ml. of methyl iodide, 2.8 g. K_2CO_3 , and 50 ml. acetone for 6 hr. at 60°, and recrystallized from ethanol (1 g. in 16 ml.), it formed six-sided plates melting at 157.0–158.5°.

Anal. Calcd. for $C_{22}H_{18}O_4$: C, 76.27; H, 5.20; mol. wt. 346. Found: C, 76.12; H, 5.71; mol. wt. 346.

o-(2,4-dihydroxybenzhydryl)benzoic acid (III). The reduction of I to the acid was best accomplished as follows: 5 g. Raney alloy was added over a period of 20 min. to a stirred solution of 15.9 g. of I in 60 ml. 2.5*N* sodium hydroxide. The temperature rose to 55–60°. As soon as the orange color disappeared, the mixture was filtered to remove the nickel. The light orange filtrate, on acidification, yielded a gummy precipitate which was then treated with hot water. On cooling overnight, it became hard (14.7–15.5 g., m.p. 175–181°).

This acid was purified by dissolving it in absolute ether (1 g. in 30 ml.), and evaporating the filtrate to a small volume (5 ml.). The crystals thus obtained contained one mole of solvate ether, which was lost at 120°. (Calcd. for $C_{20}H_{16}O_4 \cdot (C_2H_5)_2O$: Ether, 18.8%. Found, loss in weight: 19.0 ± 0.3%). The yield, in the form of two crops, was 7.6–10.4 g., m.p. 184–186° (47–65°).

This same acid may be prepared by the zinc dust reduction of I in 80% acetic acid, in which case some V is obtained as the part which is insoluble in 2*N* sodium carbonate.

The pure III melts at 186.9–187.4° (Pechmann,² 184°).

Anal. Calcd. for $C_{20}H_{16}O_4$: C, 75.00; H, 5.00; mol. wt. 320. Found: C, 75.03; H, 5.75; neut. equiv. 318.

This acid is very soluble in acetone, ethanol, ethyl acetate, and acetic acid; insoluble in chloroform or benzene. It may also be recrystallized from 20% acetic acid (1 g. in 6 ml.).

I dissolves in concd. sulfuric acid with yellow color, becoming dark green. Its solution in dilute alkalies, initially colorless, slowly turns orange.

Methyl ester of III. Diazomethane, made from 5.2 g. nitrosomethylurea, was distilled into a solution of 8.0 g. of III in 200 ml. pure ether. On evaporation of most of the solvent, white crystals (m.p. 186–194°) formed. Sometimes, an oil is left which, on treatment with benzene, becomes crystalline.

The ester was purified by dissolving it in a large volume of ether and then distilling off most of the ether; or from a mixture of 1 vol. of methanol and 5 vol. of benzene. The pure ester forms white crystals melting at 203.6–204.4°.

Anal. Calcd. for $C_{21}H_{18}O_4$: C, 75.45; H, 5.39. Found: C, 75.24; H, 5.70.

Triacetyl derivative of 10-(o,p-dihydroxyphenyl)-9-anthrol (IV). By heating 3.2 g. of III in 5 ml. acetic anhydride and 0.03 ml. of concd. sulfuric acid for 30 min. to 120°, and recrystallizing the crude product from 230 ml. ethanol, 3.1–3.5 g. of IV, m.p. 181–185° were obtained. After crystallizations from ethyl acetate (1 g. in 12 ml.), the pure compound melted at 183.4–184.0°. Solutions of IV in organic solvents exhibit blue fluorescence.

Anal. Calcd. for $C_{26}H_{20}O_6$: C, 72.89; H, 4.67. Found: C, 72.78; H, 4.69.

A mixture of this compound with the acetyl derivatives (m.p. 179–181°) of the condensation product obtained from resorcinol and 9-bromo-10-anthrone by the procedure of Liebermann and Mamlock⁹ melted at 182–183°.

The ε-lactone of α-(2,4-dihydroxyphenyl)-α-(phenyl)-o-toluic acid (V). When III (1.60 g.) was heated to 220°, it gave off one mole water (85 mg.) and a trace of carbon dioxide (2 mg.). The resulting compound, obtained in practically quantitative yield, was crystallized from ethanol (1 g. in 12 ml.). It may also be purified by sublimation at 200° and 10 microns pressure. The pure V melts at 242.0–242.5° and dissolves in *N* sodium hydroxide to a colorless solution.

Anal. Calcd. for $C_{20}H_{14}O_3$: C, 79.46; H, 4.76; mol. wt. 302. Found: C, 79.41; H, 4.71; mol. wt. 315.

When a suspension of 0.75 g. of V in 10 ml. of *N* sodium carbonate is refluxed under nitrogen for 5 hr. and the resulting solution is acidified, then III will precipitate out.

Acetyl derivative of V (Va). On heating 1.0 g. of V, 1.5 ml. acetic anhydride, and 0.02 ml. concd. sulfuric acid for 30 min. to 120° and recrystallizing the product from 12 ml. ethyl acetate, 0.78 g. (m.p. 174–175°) was obtained.

This same acetyl derivative is obtained as the main product by direct acetylation of III with acetic anhydride and sodium acetate.

The pure Va melts at 174.6–175.3°.

Anal. Calcd. for $C_{22}H_{18}O_4$: C, 76.73; H, 4.68; mol. wt. 344. Found: C, 76.70; H, 4.73; mol. wt. 345.

The methyl ether of V or the ε-lactone of α-(2-hydroxy-4-methoxyphenyl)-α-(phenyl)-o-toluic acid (Vb). A mixture of 3.02 g. of V, 1.4 g. of K_2CO_3 , and 50 ml. acetone were heated for 8 hr. on a water bath of 60°. The resulting compound, recrystallized from ethanol (1 g. in 80 ml.), melted at 191.9–192.7°.

Anal. Calcd. for $C_{21}H_{16}O_3$: C, 79.73; H, 5.09; $-OCH_3$, 9.8. Found: C, 79.29; H, 5.25; $-OCH_3$, 10.0.

On heating this methylether with *N* sodium hydroxide, it gradually dissolved. On acidification, an oil separated, which could not be made to crystallize. When heating this amorphous acid to 200°, it was transformed back into Vb.

o-(2,4-dihydroxybenzhydryl)benzyl alcohol (VI). This alcohol was prepared according to the procedure given for phenolphthalol.¹⁰ The extraction thimble was charged with 12.8 g. of III, and the flask with a solution of 5.0 g. of $LiAlH_4$ in 500 ml. pure ether. The thimble content was dissolved during the first 2 to 3 hr. of a total of 24 hr. of refluxing. The quantity of unreacted III was negligible. The oily residue, left after the evaporation of the ether, was dissolved in 200 ml. of 20% ethanol, stirring the solution while slowly cooling. The 10.4–11.2 g. of crystals (m.p. 168–169°; yield 85–91% based on III) were recrystallized from water (1 g. in 450 ml.; recovery 75–81%). The pure VI melts at 169.8–170.4°.

Anal. Calcd. for $C_{20}H_{18}O_3$: C, 78.42; H, 5.92; mol. wt. 306. Found: C, 78.47; H, 6.16; mol. wt. 320.

This alcohol is very soluble in acetone, ethanol, *n*-butanol, cyclohexanone; soluble in ether; insoluble in chloroform. As expected, its solution in *N* sodium hydroxide is colorless.

Triacetyl derivative of VI. A mixture of 3.06 g. of VI, 6 ml. acetic anhydride, and 0.02 ml. concd. sulfuric acid was heated for 1 hr. to 100°. The 4.1–4.4 g. dry crude acetyl derivative was placed in a thimble and extracted with pure ether. The compound crystallized from the ether in the form of fine white needles after standing for several days at 5° (yield 3.1–3.6 g., m.p. 103–105°). The pure triacetyl derivative melted at 104.1–105.5°.

Anal. Calcd. for $C_{26}H_{24}O_6$: C, 72.22; H, 5.56; mol. wt. 432. Found: C, 72.19; H, 5.29; mol. wt. 422.

Tribenzoyl derivative of VI. To a solution of 1.0 g. of VI in 2 ml. of pyridine was added 2 ml. of benzoyl chloride. The mixture was kept for 0.5 hr. at 120°, and was then poured into ice water. The gummy precipitate, washed free of pyridine, very slowly became crystalline. Recrystallized from a large amount of ethanol, it formed colorless needles, m.p. 141.1–142.2°.

Anal. Calcd. for $C_{41}H_{30}O_6$: C, 79.60; H, 4.89; mol. wt. 618. Found: C, 79.82; H, 5.07; mol. wt. 592.

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(9) C. Liebermann and L. Mamlock, *Ber.*, **38**, 1798 (1905).

(10) M. H. Hubacher, *J. Am. Chem. Soc.*, **74**, 5216 (1952).