[CONTRIBUTION FROM THE BAKER LABORATORY OF CHEMISTRY OF CORNELL UNIVERSITY]

2,4-DIHYDROXYBENZOYL-ORTHO-BENZOIC ACID AND SOME OF ITS DERIVATIVES[1]

BY W. R. ORNDORFF AND EMIL KLINE

RECEIVED MAY 12, 1924 PUBLISHED OCTOBER 4, 1924

From work done in this Laboratory it seems highly probable that the formation of the phthaleins by the condensation of a phenol and phthalic anhydride takes place in two stages. First, the phenol and anhydride form an addition product, which then reacts with a second molecule of the phenol with the loss of water to form the phthalein. According to this view, the formation of fluorescein by the condensation of resorcinol and phthalic anhydride should take place with the intermediate formation of 2,4-dihydroxybenzoyl-*o*-benzoic acid. This investigation was therefore undertaken to see whether dihydroxybenzoyl-benzoic acid could be prepared from resorcinol and phthalic anhydride, to determine the part the acid plays in the preparation of fluorescein, to study its properties and reactions and to prepare and study some of its derivatives.

2,4-Dihydroxybenzoyl-*o*-benzoic acid was first made by Baeyer[2] (who called it *monoresorcinphthalein*) by decomposing fluorescein with a concentrated solution of sodium hydroxide. According to him the acid separates from dil. alcohol in yellow crystals which melt at 200° and contains one molecule of water of crystallization. Heated with resorcinol or heated alone above its melting point, it was converted into fluorescein. Baeyer's analyses indicate that his product was not pure. He also states that he could not prepare crystallized salts of the acid.

Meyer and Conzetti[3] prepared 2,4-dihydroxybenzoyl-*o*-benzoic acid by heating fluorescein chloride in a solution of potassium hydroxide at 230°. The acid was also obtained by Hans Liebig[4] using the method employed by Baeyer. Liebig states that the acid crystallizes from water with $1^1/_2$ molecules of water of crystallization and melts at 210–211°. When it was heated to 220–240° he claims to have obtained two modifications of fluorescein, one red and the other yellow, γ-fluorescein, $(C_{20}H_{12}O_5)_4+H_2O$.

2,4-Dihydroxybenzoyl-*o*-benzoic acid has been prepared recently by O. Fisher and Bollman.[5] They heated a mixture of phthalic anhydride and resorcinol in the presence of dehydrated boric acid for one and a

---

[1] This article is based upon a thesis submitted to the Faculty of the Graduate School of Cornell University by Emil Kline, Grasselli Fellow in Chemistry, in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

[2] Baeyer, *Ann.*, **183**, 23 (1876).

[3] Meyer and Conzetti, *Ber.*, **30**, 970 (1897).

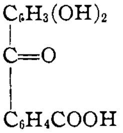
[4] Liebig, *J. prakt. Chem.*, **85**, 261 (1912).

[5] Fisher and Bollman, *ibid.*, **104**, 123 (1922).

half hours at 160–165°. Purification involved the precipitation of the fluorescein formed in the reaction as fluorescein hydrochloride, the acid being then crystallized from hot 40% alcohol and finally from hot water. This product was nearly colorless and melted at 208–209° to a reddish-yellow oil. According to their analyses the acid contained no water of crystallization.

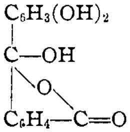
2,4-Dihydroxybenzoyl-tetrachloro-*o*-benzoic acid was made in this Laboratory by Orndorff and Adamson[6] by heating tetrachloro-phthalic acid with resorcinol without a condensing agent. They found that when heated alone or with resorcinol it gave tetrachloro-fluorescein.

In determining the structure of 2,4-dihydroxybenzoyl-*o*-benzoic acid, Graebe, Kohn and Huguenin[7] considered the two formulas,



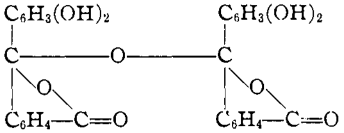
$$\begin{array}{l} C_6H_3(OH)_2 \\ | \\ C{=}O \\ | \\ C_6H_4COOH \end{array}$$

I

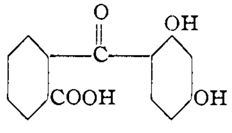


II

and concluded that Formula II best represents the substance, since it explains better the formation of the acid, the ease with which it is converted into fluorescein, the inability to transform it into a derivative of anthraquinone and finally the fact that the acid, when treated with acetyl chloride, was converted into an acetyl derivative which, when heated with a solution of sodium hydroxide, gave a compound with the constitution III.



III



IV

The positions of the hydroxyl groups were determined by Heller[8] who gave the acid Formula IV.

Very similar to the dihydroxy acid is *p*-hydroxybenzoyl-*o*-benzoic acid, first made by Friedlaender[9] by hydrolyzing phenolphthalein oxime, and later by Orndorff and Murray[10] using the same method. An anhydride of this acid was made by the latter workers, which is similar to the compound obtained by Graebe[7] from dihydroxybenzoyl-benzoic acid. From the fact that phenolphthalein and several mixed phthaleins were prepared from *p*-hydroxybenzoyl-*o*-benzoic acid, Orndorff and Murray conclude

---

[6] Orndorff and Adamson, This Journal, **40,** 1239 (1918).

[7] Graebe, Kohn and Huguenin. *Arch. sci. phys. nat.*, **30,** 91 (1893).

[8] Heller, *Ber.*, **28,** 315 (1895).

[9] Friedlaender, *Ber.*, **26,** 176 (1893).

[10] Orndorff and Murray, This Journal, **39,** 679 (1917).

that the condensation of phenol and phthalic anhydride to give phenolphthalein probably takes place in two stages and that *p*-hydroxybenzoyl-*o*-benzoic acid is an intermediate product. This view has been confirmed by the work of Ullmann and Schmidt,[11] who have shown that *p*-hydroxybenzoyl-*o*-benzoic acid is readily formed by heating phenol with phthalic anhydride in solution in acetylene tetrachloride in the presence of aluminum chloride.

Experimental Part

All melting points given in the following pages are uncorrected and were made in an electrically heated, Dennis melting-point apparatus[12] using a standard thermometer. In order to bring substances to constant weight and to determine solvent of crystallization, an electrically heated tube[13] was used. The solubility of the various compounds in the different solvents is stated only approximately, Mulliken's[14] classification being used.

Preparation of 2,4-Dihydroxybenzoyl-*o*-benzoic Acid.—When pure phthalic anhydride and pure resorcinol are heated together without a condensing agent at 126° they react, forming 2,4-dihydroxybenzoyl-*o*-benzoic acid and some fluorescein. The use of boric acid in this reaction, as employed by Fisher and Bollman,[5] is entirely unnecessary.

Forty-five g. of phthalic anhydride and 40 g. of resorcinol were heated together for 24 hours, the temperature being held at 126°. The reddish-brown fused mass was extracted several times with boiling water and the solution filtered from the fluorescein. Reddish-yellow crystals soon began to settle out of the filtrate. These were quickly filtered off, since they contained much fluorescein. On standing, four crops of yellow crystals which melted at 197–200° were obtained. The yield of the crude acid was 57 g., or 67.9%.

The acid was purified by recrystallizing it thrice from hot water, the fluorescein which separated being filtered off each time before crystallization began. It was then precipitated from its solution in 5% aqueous sodium hydroxide by adding hydrochloric acid until the solution was faintly acid, filtering, and then strongly acidifying the filtrate, when the greater part of the dihydroxy acid precipitated much lighter in color, but still yellow. This product was then crystallized first from methyl alcohol, the solution being boiled with boneblack, then four times from a mixture of methyl alcohol and benzene (3:1) and finally from hot water. The resulting acid was *colorless* and crystallized in small needles melting at 208–209°, with decomposition.

An investigation of the mother liquors as well as the insoluble products formed in this reaction showed that the only substances present besides the dihydroxy acid were fluorescein, a small amount of tar, unchanged resorcinol and phthalic acid. This indicates that fluorescein and some tar are the impurities which cause the color in the crude acid and further

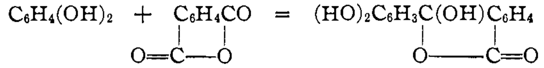
[11] Ullmann and Schmidt, *Ber.*, **52,** 2098 (1919).

[12] Dennis, *J. Ind. Eng. Chem.*, **12,** 366 (1920).

[13] *Am. Chem. J.*, **48,** 477 (1912).

[14] Mulliken, "Identification of Pure Organic Compounds," John Wiley and Sons, **1904,** vol. I, p. 38.

that fluorescein and 2,4-dihydroxybenzoyl-*o*-benzoic acid are the only products of the reaction between phthalic anhydride and resorcinol. The equation for the formation of the acid is,

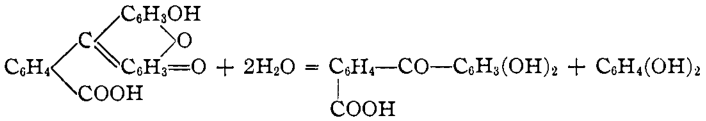


$$C_6H_4(OH)_2 + \begin{array}{c}C_6H_4CO\\ |\quad\ |\\ O{=}C{-}O\end{array} = \begin{array}{c}(HO)_2C_6H_3C(OH)C_6H_4\\ |\qquad\quad |\\ O{-\!-\!-}C{=}O\end{array}$$

This is analogous to the formation of benzoylbenzoic acid from phthalic anhydride and benzene in the presence of aluminum chloride[15] and to the formation of 2,4-dihydroxybenzoyl-tetrachloro-*o*-benzoic acid by the combination of resorcinol and tetrachloro-phthalic acid.[6]

2,4-Dihydroxybenzoyl-*o*-benzoic acid was also made by the decomposition of the fluorescein formed in the above reaction by sodium hydroxide. A yield of 89.5% was obtained, the crude material melting at 201–204°. Purification was brought about by the method given above. The acid separated from the aqueous solution, on cooling, in small, *colorless* needles melting at 208–209°, with decomposition.

The formation of the dihydroxy acid by the decomposition of fluorescein by alkali is shown by the equation,



Fluorescein Dihydroxy acid Resorcinol

The dihydroxybenzoyl-benzoic acid made from phthalic anhydride and resorcinol is identical with the acid obtained by the decomposition of fluorescein. When heated with fused sodium acetate and acetic anhydride both give the same tri-acetate.[16] Furthermore, both products, as well as a mixture of the two, had the same melting point.

The acid crystallizes from water with one molecule of water of crystallization as shown by the following analyses on some of the pure acid, which had been dried in a desiccator over calcium chloride.

Anal. Subs., 0.2130, 0.2344: loss (H_2O) at 105°, 0.0142, 0.0152. Calc. for $C_{14}H_{10}O_5 + H_2O$: H_2O, 6.52. Found: 6.66, 6.48.

Subs., 0.2467: CO_2, 0.5508; H_2O, 0.0999. Calc. for $C_{14}H_{10}O_5 + H_2O$: C, 60.85; H, 4.38. Found: C, 60.91; H, 4.53.

A determination of the molecular weight of the acid by titration with 0.1 *N* sodium hydroxide solution, using methyl red as indicator, confirmed these analyses.

Mol. wt. Subs., 0.4994, 0.5045: 17.96, 18.31 cc. of 0.1 *N* NaOH. Calc. for $C_{14}H_{10}O_5 + H_2O$: mol. wt., 276.17. Found: 277.88, 275.36.

These results show further that the acid titrates as a monobasic acid. Combustion analyses on the acid, dried to constant weight at 105°, gave the following results.

Anal. Subs., 0.2882, 0.2601: CO_2, 0.6906, 0.6190; H_2O, 0.1041, 0.0929. Calc. for $C_{14}H_{10}O_5$: C, 65.11; H, 3.91. Found: C, 65.37, 64.9; H, 4.04, 4.00.

When crystallized from methyl alcohol, the acid contains one molecule of methyl alcohol of crystallization.

---

[15] See Pechmann, *Ber.*, **13,** 1612 (1880).

[16] See below.

Methyl alc. of cryst. Subs., 0.2577: loss at 115°, 0.0281. Subs., 0.2912: CO_2, 0.6619; H_2O, 0.1289. Calc. for $C_{14}H_{10}O_5 + CH_3OH$: CH_3OH, 11.04; C, 62.05; H, 4.86. Found: CH_3OH, 10.90; C, 62.01; H, 4.95.

The same sample, after it had been dried at 115°, was also analyzed.

Anal. Subs., 0.2296: CO_2, 0.5477; H_2O, 0.0786. Calc. for $C_{14}H_{10}O_5$: C, 65.11; H, 3.91. Found: C, 65.07; H, 3.83.

Combustion analyses on the acid, crystallized from benzene, which lost no weight on heating to 135–145°, gave the following results.

Anal. Subs., 0.1858, 0.2255: CO_2, 0.4435, 0.5372; H_2O, 0.0693, 0.0803. Calc. for $C_{14}H_{10}O_5$: C, 65.11; H, 3.91. Found: C, 65.12, 64.99; H, 4.17, 3.98.

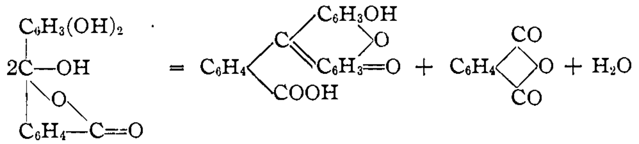
2,4-Dihydroxybenzoyl-*o*-benzoic acid, when *pure,* is *colorless* and melts at 208–209°, with decomposition, forming a red liquid. Previous investigators, who have described the acid as yellow or nearly colorless, did not succeed in obtaining a perfectly pure product. The *pure* acid dissolves in water and in a concentrated solution of ammonium hydroxide forming *colorless* solutions. It dissolves in aqueous 5% sodium hydroxide giving a yellow solution from which hydrochloric acid precipitates the acid unchanged. Concd. sulfuric acid dissolved it forming a red solution, but the dihydroxy acid may be recovered from this solution unchanged by diluting with water.

2,4-Dihydroxybenzoyl-*o*-benzoic acid is very soluble in ethyl acetate, acetone, ether, alcohol, glacial acetic acid; soluble in methyl alcohol and hot water; very difficultly soluble in chloroform, carbon tetrachloride, hot benzene and cold water and practically insoluble in cold benzene. The solubility of the acid in the following solvents at 21° was determined.

Solvent	Parts of solvent which dissolve 1 part of acid	G. of acid soluble in 100 cc. of solvent
Water	1919.4	0.0521
Benzene	4504.5	0.0195
Methyl alcohol	33.13	2.39
95% Alcohol	3.34	24.61

A solution of ferric chloride gives a distinctive test with 2,4-dihydroxybenzoyl-*o*-benzoic acid and its esters. When about 0.1 g. of the acid is dissolved in 5 cc. of water and a drop of a 10% ferric chloride solution added, the solution becomes deep red.

Fluorescein from Dihydroxybenzoyl-benzoic Acid.—2,4-Dihydroxybenzoyl-*o*-benzoic acid does not yield an anhydride on heating, similar to that obtained by Orndorff and Murray[10] in the case of *p*-hydroxybenzoyl-benzoic acid, but is converted into fluorescein, phthalic anhydride and water according to the equation,



2 Mols. of acid Fluorescein Phthalic anhydride

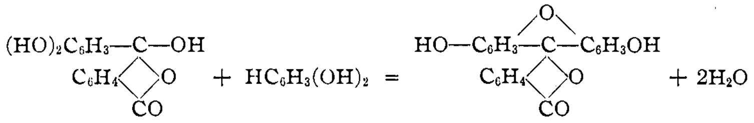
According to Hans Liebig,[4] when the acid is heated above its melting point and the resulting mass extracted first with ether and then with alcohol, one variety of fluorescein remains undissolved while a second variety dissolves in the alcohol. The insoluble fluorescein, recrystallized from methyl alcohol, had the formula $C_{20}H_{12}O_5+CH_3OH$, while the soluble fluorescein was obtained as the so-called γ-fluorescein with the formula: $(C_{20}H_{12}O_5)_4+H_2O$. On repeating Liebig's work, the authors obtained the insoluble fluorescein as described.

The fluorescein obtained from the alcohol extract, however, did not correspond to Liebig's γ-fluorescein. It was orange in color and not yellow, as Liebig describes his product, and when heated to constant weight at 150°, the loss in weight was more than could be accounted for by his formula. A combustion analysis on this product, dried at 150°, shows that it is fluorescein.

Anal. Subs., 0.1985: CO_2, 0.5279; H_2O, 0.0614. Calc. for $C_{20}H_{12}O_5$: C, 72.27; H, 3.64. Found: C, 72.55; H, 3.46.

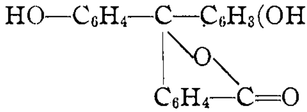
That dihydroxybenzoyl-benzoic acid is partly converted into fluorescein when heated to 150–170° for a long time was shown by converting the product thus obtained into an acetyl derivative which, when recrystallized from alcohol, melted at 200°, proving it to be fluorescein diacetate.

As Baeyer[2] has already shown, fluorescein is also formed when the dihydroxy acid is heated with resorcinol. There can be no doubt, therefore, that the formation of fluorescein takes place in two stages and that 2,4-dihydroxybenzoyl-*o*-benzoic acid is the intermediate product. The reaction is,



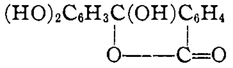
Dihydroxy acid Resorcinol Fluorescein (lactoid)

When heated with phenol, phenolresorcinolphthalein, the dihydroxy acid,



together with some fluorescein, is formed.

2,4-Dihydroxybenzoyl-*o*-benzoic acid is a γ-ketone acid and, as it is colorless and forms a colorless triacetate, it has the lactone structure (V) in the free condition, but the ketone structure (VI) in the form of its metallic salts and esters.



$$\begin{array}{l}(HO)_2C_6H_3C(OH)C_6H_4\\ \quad O\text{———}C{=}O\end{array}$$

V

$(HO)_2C_6H_3—CO—C_6H_4COOM$

VI

Orndorff and Kelley[17] have suggested similar structures for *p*-hydroxybenzoyl-*o*-benzoic acid and its salts.

Contrary to the statement of Baeyer, the acid forms well-crystallized salts.[18]

Ammonium Salt.—The dry dihydroxy acid took up 3.5 molecules of dry ammonia gas. In a desiccator over sulfuric acid this salt lost the excess of ammonia and gave a nearly colorless *mono-ammonium* salt, which when heated in a current of dry air at 50° did not lose any further weight.

Sodium and Potassium Salts.—These were made by dissolving the acid in solutions of the hydroxides and recrystallizing them from alcohol. They are very soluble in water and are soluble in the alcohols. The sodium salt crystallizes with two molecules of water, the potassium salt without water.

The Silver Salt was made from alcoholic solutions of the acid and silver nitrate. It contains one molecule of water of crystallization and is difficultly soluble in water and the alcohols. On boiling these solutions reduction to metallic silver takes place.

Barium, Calcium and Zinc Salts were made by boiling a solution of the acid with the carbonates and crystallizing the salts from water. The barium salt crystallizes with two, the calcium with three and the zinc salt with seven molecules of water of crystallization. The barium salt is soluble in hot water and only slightly soluble in cold. It is insoluble in absolute alcohol. The calcium salt is very soluble in water and the alcohols. The zinc salt crystallizes in colorless needles that melt at 80–90°. It is also formed when a solution of the acid is boiled with zinc dust, no reduction taking place.

The Lead Salt was made from lead carbonate. It crystallizes from water with a molecule of the acid plus three molecules of water of crystallization.

Tri-acetate.—Forty g. of 2,4-dihydroxybenzoyl-*o*-benzoic acid was boiled with an equal weight of fused sodium acetate and 250 cc. of acetic anhydride for three hours. The solution was then poured into cold water, the acetyl derivative precipitating as a nearly colorless, somewhat oily solid which became crystalline on standing. It was recrystallized several times from absolute alcohol and then from methyl alcohol, the pure acetate melting at 134–135°. When recrystallized from a mixture of ethyl acetate and ether (1:4), and from a mixture of benzene and ether (1:4), the product in both cases melted at the same temperature. Combustion analyses show that the substance is a triacetate.

Anal. Subs., 0.2487, 0.2365: CO_2, 0.5673, 0.5423; H_2O, 0.0951, 0.0894. Calc. for $C_{14}H_7O_5(C_2H_3O)_3$: C, 62.48; H, 4.20. Found: C, 62.23, 62.55; H, 4.28, 4.23.

The number of acetyl groups was also determined using a modification of the Wenzel method.[19]

Acetyl groups. Subs., 0.2005, 0.1963, 0.2011: 0.07, 0.07, 0.05 cc. of 0.1 *N* iodine; 15.63, 15.24, 15.61 cc. net of 0.1 *N* NaOH. Calc. for $C_{14}H_7O_5(C_2H_3O)_3$: C_2H_3O, 33.60. Found: 33.40. 33.26, 33.29.

These results leave no doubt that the substance is a *tri-acetate* of dihydroxybenzoylbenzoic acid and not a *diacetate* as Hans Liebig[4] calls the product which he obtained in the same way. The tri-acetate is very soluble in ethyl acetate, benzene, hot methyl alcohol and hot absolute alcohol; difficultly soluble in cold ethyl and methyl alcohols;

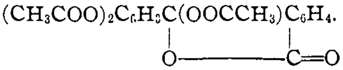
---

[17] Orndorff and Kelley, This Journal, **44,** 1518 (1922).

[18] Further details regarding these salts, including the analytical data, will be found in the dissertation of Dr. Kline in the library of Cornell University.

[19] Wenzel, *Monatsh.*, **18,** 659 (1897). See also Orndorff and Brewer, *Am. Chem. J.*, **26,** 121 (1901); and Orndorff and Delbridge, *ibid.*, **42,** 227 (1909).

insoluble in water and ether. It is readily saponified in the cold by alcoholic sodium hydroxide solution in which it dissolves forming a red solution. With acids this solution gives the dihydroxy acid and a very small quantity of a reddish-brown substance which is probably identical with the orange anhydride described below. The formula of the tri-acetate is



$$(CH_3COO)_2C_6H_3C(OOCCH_3)C_6H_4 \qquad O\text{———}C{=}O$$

Action of Acetic Anhydride on 2,4-Dihydroxybenzoyl-*o*-benzoic Acid.—When 20 g. of the dihydroxy acid was acetylated by boiling with an excess of acetic anhydride, 9 g. of colorless needles crystallized from the anhydride which, when recrystallized from glacial acetic acid, melted at 135–136°. This substance is not the tri-acetate just described, since a mixture of it and the pure tri-acetate melted at 115°. Combustion analyses on a sample, dried at 110°, were made.

Anal. Subs., 0.2483, 0.2058, 0.2250: CO_2, 0.6222, 0.5107, 0.5595; H_2O, 0.0806, 0.0661, 0.0726. Calc. for $C_{14}H_7O_4(COCH_3)$: C, 68.07; H, 3.57. Found: C, 68.36, 67.70, 67.84; H, 3.63, 3.59, 3.61.

The analyses prove that it is not the tri-acetate. Moreover, it differs by a molecule of water from the mono-acetate which Fisher and Bollman[5] obtained by the same procedure and which they state melts at 161°. It is very soluble in glacial acetic acid, ethyl acetate, acetone and benzene and insoluble in ether, petroleum ether and water. When crystallized from dil. ethyl alcohol, it gave colorless plates that melted at 62–66°, while from methyl alcohol it separated in colorless plates melting at 110°. Crystallization from benzene or mixtures of benzene and ether, acetone and ether and ethyl acetate and ether did not change the melting point. When crystallized from *dil.* acetic acid, however, it gave Fisher and Bollman's mono-acetate melting at 161–162° and when hydrolyzed with sulfuric acid it gave acetic acid, showing it to be an acetate. These facts and the analyses indicate that the substance is an anhydride of the mono-acetate of the dihydroxy acid.

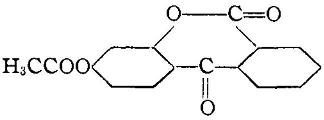
A sample of the product crystallized from methyl alcohol and melting at 110°, was dried at 85° and analyzed.

Anal. Subs., 0.3127, 0.2191: CO_2, 0.7391, 0.5186; H_2O, 0.1241, 0.0895. Calc. for $C_{14}H_8O_5(C_2H_3O)(CH_3)$: C, 64.95; H, 4.49. Found: C, 64.49, 64.57; H, 4.44, 4.57.

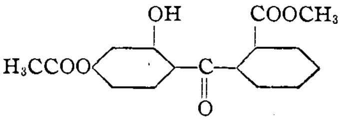
From these analyses and its method of preparation this substance is the methyl ester of the mono-acetate of dihydroxybenzoyl-benzoic acid, the product melting at 62–66° being the ethyl ester.

Both of these acetyl derivatives are converted into the dihydroxy acid when boiled with sodium hydroxide solution in which they dissolve to give a yellow liquid.

The formulas of the anhydride of the mono-acetate and of the methyl ester of the mono-acetate are as follows:



Anhydride of the
Mono-acetate



Methyl ester of the
Mono-acetate

In spite of several attempts, the mono-acetate of Fisher and Bollman,[5] melting at 161°, could not be obtained as the product of the acetylation with acetic anhydride. In a few instances when the acetic anhydride solution was concentrated to a sirup, a very small amount of this product separated which, when recrystallized from glacial acid melted at 157–159°.

After the separation of the acetyl derivative melting at 135°, the acetic anhydride mother liquor was poured into water. The main product of the acetylation was precipitated as a cream-colored solid which, however, could not be obtained in a crystalline condition, although it is very soluble in most organic solvents. It is saponified in the cold by sodium hydroxide solution in which it dissolves giving a red liquid. When this solution is acidified, about equal amounts of the dihydroxy acid and a light brown substance are precipitated, the latter being probably the orange anhydride described below.

Action of Acetyl Chloride on 2,4-Dihydroxybenzoyl-*o*-benzoic Acid.—A. Ten g. of *yellow* dihydroxy acid was boiled with 75 cc. of acetyl chloride for two hours and the excess of acetyl chloride distilled under reduced pressure. A white residue was obtained in the flask, most of which dissolved when boiled with absolute alcohol. A small portion apparently insoluble in boiling alcohol was filtered off, washed with alcohol, dried at 110° and analyzed.

Anal. Subs., 0.1947: CO_2, 0.4730; H_2O, 0.0684. Calc. for $(C_{14}H_8O_4)_2O(C_2H_3O)_2$: C, 65.97; H, 3.81. Found: C, 66.27; H, 3.93.

This substance lost 2.01% when heated at 110° and did not melt up to 300°. It dissolves in 5% sodium hydroxide solution giving a *deep* purple liquid and from the analysis appears to be an isomer of the diacetate of the dihydroxybenzoyl-benzoic anhydride which dissolves in the alcohol.

From the alcoholic filtrate a cream-colored crystalline powder separated, which was recrystallized thrice from absolute alcohol. The final product was colorless and did not melt up to 350°. A sample was dried at 130° and analyzed.

Anal. Subs., 0.1938, 0.2186, 0.2068: CO_2, 0.4709, 0.5312, 0.5017; H_2O, 0.0715, 0.0767, 0.0752. Calc. for $(C_{14}H_8O_4)_2O(C_2H_3O)_2$: C, 65.97; H, 3.81. Found: C, 66.28, 66.29, 66.18; H, 4.13, 4.14, 4.07.

These results indicate that the product is the diacetate of dihydroxybenzoyl-benzoic anhydride. It is insoluble in water, ether and benzene; soluble in hot absolute alcohol and hot methyl alcohol, very soluble in glacial acetic acid and ethyl acetate. It is saponified in the cold by aqueous sodium hydroxide, forming a *deep* purple solution which changes to red when heated or allowed to stand. When this solution was boiled and acidified, an orange-colored, flocculent precipitate containing a small amount of the dihydroxy acid resulted. This product was purified by extracting with boiling water and dissolving the residue in alcohol from which solvent it separated on the addition of water as an orange-colored, *amorphous* powder. Combustion analyses on a sample, dried at 120°, were made.

Anal. Subs., 0.2376, 0.2135, 0.1964: CO_2, 0.6110, 0.5455, 0.5066; H_2O, 0.0784, 0.0645, 0.0606. Calc. for $C_{14}H_8O_4$: C, 69.99; H, 3.35: calc. for $(C_{14}H_9O_4)_2O$: C, 67.46; H, 3.64. Found: C, 70.15, 69.70, 70.37; H, 3.69, 3.38, 3.45.

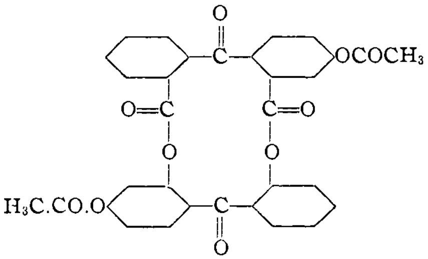
The substance is therefore an anhydride of dihydroxybenzoyl-benzoic acid formed by the loss of one molecule of water from one molecule of the acid and not the anhydride, $(C_{14}H_9O_4)_2O$, which Graebe[7] states he obtained by the same method. It was not obtained crystalline and does not melt up to 350°. It is soluble in alcohol, glacial acetic acid, ethyl acetate, methyl alcohol; practically insoluble in benzene, toluene, ether and water. It dissolves in aqueous sodium hydroxide giving a deep red solution and was recovered unchanged from a 20% sodium hydroxide solution which had been boiled for 25 hours.

As the analyses of this anhydride did not agree with the composition of the anhydride which Graebe[7] made by the same method, the work was repeated with the *pure* acid.

B. Ten g. of *pure* dihydroxy acid[20] was boiled with 75 cc. of acetyl chloride for two hours and the solution set aside. Small, colorless needles separated and after distillation of some of the acetyl chloride under reduced pressure, a second crop of similar crystals was obtained. Recrystallizing the product from glacial acetic acid and then from absolute alcohol gave colorless needles melting at 291–293° with decomposition. A sample of this material, which lost no weight when dried at 150°, was analyzed.

Anal. Subs., 0.2090, 0.1884; CO_2, 0.5238, 0.4702; H_2O, 0.0658, 0.0593. Subs., 0.2330, 0.2902: 8.07, 9.92 cc. net of 0.1 *N* NaOH. Calc. for $(C_{14}H_7O_4)_2(C_2H_3O)_2$: C, 68.07; H, 3.57; C_2H_3O, 15.22. Found: C, 68.37, 68.09; H, 3.52, 3.52; C_2H_3O, 14.91, 14.71.

The melting point, crystal form and analyses show that this product is not the diacetate of the anhydride obtained under "A" above. Furthermore, it is practically insoluble in cold sodium hydroxide solution, but when the mixture is boiled a red solution is obtained, giving the dihydroxy acid with only a small amount of the orange anhydride. The structure of this compound may be represented as follows.



The anhydride described by Graebe could not be obtained.

Action of Thionyl Chloride on 2,4-Dihydroxybenzoyl-*o*-benzoic Acid.—A. Twenty g. of *yellow* dihydroxy acid was boiled with 20 g. of thionyl chloride for one hour, during which all dissolved giving a deep red solution. The excess of the chloride was distilled under reduced pressure and the dark red residue boiled several times with water to remove any unchanged acid and thionyl chloride. It was then repeatedly dissolved in sodium hydroxide solution and precipitated with hydrochloric acid and finally obtained from alcohol by the addition of water, as an amorphous, orange powder which did not melt up to 350°. It dissolves in sodium hydroxide solution forming a deep red liquid and closely resembles the anhydride obtained by the saponification of the diacetate of the anhydride described above. Combustion analyses on the material, dried at 115–125°, show that the two products are identical.

Anal. Subs., 0.2017, 0.2507: CO_2, 0.5204, 0.6459; H_2O, 0.0579, 0.0717. Calc. for $C_{14}H_8O_4$: C, 69.99; H, 3.35. Found: C, 70.38, 70.29; H, 3.21, 3.20.

B. The action of thionyl chloride on *pure, anhydrous* dihydroxybenzoyl-benzoic acid was also investigated. The orange-colored product obtained is identical with that just described, as shown by the following analysis on a sample, dried at 175°.

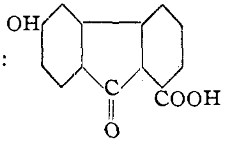
Anal. Subs., 0.2614: CO_2, 0.6730; H_2O, 0.0789. Calc. for $C_{14}H_8O_4$: C, 69.99; H, 3.35. Found: C, 70.23; H, 3.38.

Boiling with solutions of the alkalies does not convert this anhydride into the dihydroxy acid. This anhydride dissolves in the cold in a solution of sodium bicarbonate forming a red liquid and appears to give an acetate with acetic anhydride. From its

---

[20] This work was done by Mr. C. V. Shapiro. The combustion analyses were made by Miss S. Alice McNulty.

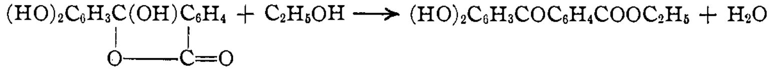
color and the fact that it is not hydrolyzed by boiling with solutions of the alkalies it may have the following structure:



Ethyl Ester of the Dihydroxy Acid.[21]—Fifteen g. of the dihydroxy acid was dissolved in 75 cc. of 95% alcohol, and 5 cc. of concd. sulfuric acid was added. The mixture was boiled for six hours and then poured into a solution of sodium carbonate. The ethyl ester separated as a brown oil which solidified on standing. It was crystallized several times from 50% alcohol. The nearly colorless crystals, melting at 133–134°, were analyzed after drying at 110°.

Anal. Subs., 0.2039, 0.2326: CO_2, 0.5030, 0.5751; H_2O, 0.0913, 0.1062. Calc. for $C_{14}H_9O_5(C_2H_5)$: C, 67.12; H, 4.93. Found: C, 67.30, 67.45; H, 5.01, 5.11.

The ester is very soluble in alcohol, ethyl acetate, methyl alcohol and ether, soluble in benzene and insoluble in water. It dissolves in cold sodium hydroxide solution without change, but when this solution is boiled and then acidified, 2,4-dihydroxybenzoyl-*o*-benzoic acid is precipitated. Concd. sulfuric acid dissolves the ester, forming a yellow solution which changes to orange when heated, probably owing to saponification. Ferric chloride solution gives a deep red color with an alcoholic solution of the ester. The formation of the ethyl ester is shown in the equation,



$$\underbrace{(HO)_2C_6H_3C(OH)C_6H_4}_{O\text{——}C=O} + C_2H_5OH \longrightarrow (HO)_2C_6H_3COC_6H_4COOC_2H_5 + H_2O$$

Methyl Ester of the Dihydroxy Acid.—This ester was prepared from the dihydroxy acid and methyl alcohol. It was crystallized from alcohol and then from methyl alcohol, forming nearly colorless crystals melting sharply at 191–192°. A sample, dried at 120–130°, was analyzed.

Anal. Subs., 0.2310, 0.2094: CO_2, 0.5583, 0.5051; H_2O, 0.0926, 0.0877. Calc. for $C_{14}H_9O_5(CH_3)$: C, 66.16; H, 4.44. Found: C, 65.94, 65.80; H, 4.49, 4.69.

The methyl ester is very soluble in ethyl acetate; soluble in ether, absolute alcohol, methyl alcohol and hot benzene and insoluble in water. It dissolves in cold sodium hydroxide solution without change, but is saponified by boiling the alkaline solution, forming dihydroxybenzoyl-benzoic acid. An alcoholic solution of the ester is colored a deep red by ferric chloride solution, and concd. sulfuric acid dissolves it giving a yellow solution.

Methyl Ester of 2,4-Dimethoxybenzoyl-*o*-benzoic Acid.[22]—Ten g. of 2,4-dihydroxybenzoyl-*o*-benzoic acid was dissolved in 100 cc. of 15% sodium hydroxide solution and dimethyl sulfate was added a little at a time while the mixture was shaken, until no further precipitate resulted. The product was crystallized twice from methyl alcohol and gave colorless needles melting at 98–99°. Combustion analyses on the product, dried at 60°, showed that it was the methyl ester of 2,4-dimethoxybenzoyl-*o*-benzoic acid.

Anal. Subs., 0.1989, 0.2041: CO_2, 0.4964, 0.5088; H_2O, 0.0953, 0.1010. Calc. for $C_{14}H_7O_5(CH_3)_3$: C, 67.98; H, 5.37. Found: C, 68.08, 68.01; H, 5.36, 5.54.

The ester is very soluble in methyl alcohol, benzene, ethyl acetate; soluble in absolute alcohol and ether. It is insoluble in water but melts when boiled with water and partially dissolves. It dissolves in cold concd. sulfuric acid forming a yellow solution,

---

[21] See (a) Tambor, *Ber.*, **43**, 1884 (1910); (b) *Chem. Zentr.*, **17**, 1890, 1610 (1913).

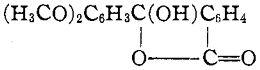
[22] See Ref. 21 a, p. 1887. Liebig, *J. prakt. Chem.*, **85**, 262 (1912).

which changes to red and then dark yellow when heated. When the yellow sulfuric acid solution formed in the cold is diluted with water the ester is precipitated. It is saponified when boiled with a solution of sodium hydroxide forming the compound described in the following paragraph.

2,4-Dimethoxybenzoyl-*o*-benzoic Acid.—Five g. of the methyl ester was boiled with 100 cc. of 5% sodium hydroxide solution for one hour and the solution acidified with hydrochloric acid. The dimethoxy acid which precipitated was recrystallized from a mixture of methyl alcohol and benzene (2:3) and then from dil. methyl alcohol. It crystallizes in colorless leaflets, melting at 164–165°. It is very soluble in absolute alcohol, ethyl acetate and methyl alcohol; soluble in ether, difficultly soluble in hot benzene and insoluble in water and cold benzene. The following analyses of the acid, dried at 125°, as well as its method of preparation show that it is 2,4-dimethoxybenzoyl-*o*-benzoic acid.

Anal. Subs., 0.1876, 0.2040: CO_2, 0.4622, 0.5002; H_2O, 0.0861, 0.0913. Calc. for $C_{14}H_8O_5(CH_3)_2$: C, 67.12; H, 4.93. Found: C, 67.21, 66.89; H, 5.14, 5.01.

Cold concd. sulfuric acid dissolves the acid giving a yellow solution, which soon changes to orange-red; as this solution is heated it becomes dark yellow. The formulas of the dimethoxy acid and its methyl ester are



$$\begin{array}{l}(H_3CO)_2C_6H_3C(OH)C_6H_4\\ \qquad\qquad\quad\; | \qquad\;\; |\\ \qquad\qquad\quad O\text{———}C{=}O\end{array}$$

$(H_3CO)_2C_6H_3COC_6H_4COOCH_3$

Acid[23] Ester

Action of Dry Ammonia Gas on Dry 2,4-Dimethoxybenzoyl-*o*-benzoic Acid.—When dry ammonia gas is passed over dry 2,4-dimethoxybenzoyl-*o*-benzoic acid, the latter takes up 1.5 molecules of ammonia, forming an unstable, colorless, mono-ammonium salt.

Anal. Subs., 0.1596, 0.1904: wt. of salt, 0.1740, 0.2076. Calc. for $C_{14}H_8O_5(CH_3)_2 + (NH_3)_{1.5}$: NH_3, 8.20. Found: 8.27, 8.29.

On standing for several days in an evacuated Hempel desiccator containing concd. sulfuric acid, this substance loses ammonia and is partially converted back into the acid.

Anal. Subs., 0.1596, 0.1904: wt. of salt, 0.1644, 0.1966. Calc. for $C_{14}H_8O_5(CH_3)_2 + (NH_3)_{0.5}$: NH_3, 2.89. Found: 2.92, 3.15.

It did not lose further weight even when heated at 80° in a current of dry air.

2,4-Dihydroxybenzoyl-*o*-benzoic Acid Phenylhydrazone.—Ten g. of the dihydroxy acid was heated with 10 g. of phenylhydrazine for three hours at 140–160°. The light brown material was boiled with water containing hydrochloric acid and then treated with alcohol, which left the phenylhydrazone undissolved and nearly colorless. It was crystallized twice from hot alcohol, from which on cooling it separates in colorless needles, melting at 260–261° and containing one molecule of alcohol. A desiccator-dried sample was used for the following analyses.

Anal. Subs., 0.3182, 0.2460: loss at 130°, 0.0386, 0.0297. Calc. for $C_{20}H_{14}O_3N_2 + C_2H_5OH$: C_2H_5OH, 12.24. Found: 12.13, 12.07.

Subs., 0.2569, 0.2553: CO_2, 0.6641, 0.6550; H_2O, 0.1322, 0.1293. Calc. for $C_{20}H_{14}O_3N_2 + C_2H_5OH$: C, 70.19; H, 5.36. Found: C, 70.52, 69.99; H, 5.76, 5.67.

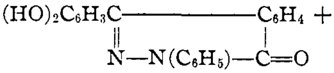
Analyses were also made on a sample dried at 130°.

Anal. Subs., 0.2796, 0.2163: CO_2, 0.7458, 0.5748; H_2O, 0.1157, 0.0966. Calc. for $C_{20}H_{14}O_3N_2$: C, 72.71; H, 4.27. Found: C, 72.77, 72.49; H, 4.63, 4.99.

The phenylhydrazone is soluble in acetone, glacial acetic acid, alcohol and methyl alcohol, difficultly soluble in ether and insoluble in benzene, petroleum ether and water.

---

[23] See Perkin and Robinson, *J. Chem. Soc.*, **93**, 510 (1908); and Ref. 21 a, p. 1887.

Its formation from the dihydroxy acid is shown by the equation, $(HO)_2C_6H_3COC_6H_4COOH + H_2N{-}NHC_6H_5 \longrightarrow$  $\begin{array}{l}(HO)_2C_6H_3C\text{—————}C_6H_4 + 2H_2O\\ \qquad\quad\;\; \| \qquad\qquad\;\; |\\ \qquad\quad\;\; N{-}N(C_6H_5){-}C{=}O\end{array}$ It is analogous to the phenylhydrazone of *o*-benzoylbenzoic acid made by Roser[24] and Meyer and Turnau[25] and to the phenylhydrazone of *p*-hydroxybenzoyl-*o*-benzoic acid made by Orndorff and Kelley.[17]

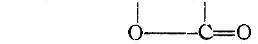
3,5-Dibromo-2,4-dihydroxybenzoyl-*o*-benzoic Acid.[26]—To a solution of 10 g. of 2,4-dihydroxybenzoyl-*o*-benzoic acid in 100 cc. of glacial acetic acid was added drop by drop and with constant shaking, 13.5 g. of bromine in 25 cc. of glacial acetic acid. When the bromination was complete, the solution was set aside and in a few minutes the dibromo acid separated in yellow crystals. It was washed with acetic acid and water, which removed the yellow color, boiled with water to remove any traces of the dihydroxy acid, then recrystallized from glacial acetic acid and finally from alcohol. This material was used for analysis, after drying at 140°.

Anal. Subs., 0.2296, 0.1917: AgBr, 0.2064, 0.1744. Calc. for $C_{14}H_8Br_2O_5$: Br, 38.43. Found: 38.26, 38.71.

The dibromo acid separates from alcohol in small, colorless crystals, melting at 224°, with decomposition. It is very soluble in ether and ethyl acetate; soluble in absolute alcohol, hot glacial acetic acid and methyl alcohol; very difficultly soluble in hot benzene and insoluble in water. It dissolves in concd. ammonium hydroxide and in cold sodium hydroxide solution giving yellow liquids and is precipitated from these solutions unchanged by the addition of hydrochloric acid. Cold, concd. sulfuric acid dissolves the acid forming a red solution, which becomes colorless when water is added, the dibromo acid being precipitated.

When heated alone above its melting point, the dibromo acid is converted into eosin and phthalic anhydride, the reaction being similar to the formation of fluorescein from the dihydroxy acid. Fifteen g. of the dibromo acid was heated for two hours at 225°, the mass boiled with water to remove the phthalic anhydride and the orange-red material dissolved in sodium hydroxide solution, precipitated by hydrochloric acid and then recrystallized from dil. alcohol to which was added some hydrochloric acid. Analysis of the flesh-colored product which separated from the alcohol solution indicates that it is tetrabromofluorescein or eosin.

Anal. Subs., 0.1849: AgBr, 0.2135. Calc. for $C_{20}H_8O_5Br_4$: Br, 49.35. Found: 49.14.

When the dibromo acid is heated with resorcinol and zinc chloride at 160–180° condensation takes place and *asymmetric* dibromofluorescein is formed.[27] The formula of the dibromo acid is  $\begin{array}{l}(HO)_2C_6HBr_2C(OH)C_6H_4.\\ \qquad\qquad\quad\;\; | \qquad\quad\;\; |\\ \qquad\qquad\quad\;\; O\text{———}C{=}O\end{array}$

Action of Dry Ammonia Gas on Dry 3,5-Dibromo-2,4-dihydroxybenzoyl-*o*-benzoic Acid.—When dry ammonia gas is passed over dry 3,5-dibromo-2,4-dihydroxybenzoyl-*o*-benzoic acid, it absorbs 3.5 molecules of ammonia, forming an unstable, yellowish-green tri-ammonium salt.

Anal. Subs., 0.2234, 0.1929: salt, 0.2549, 0.2202. Calc. for $C_{14}H_8Br_2O_5 + (NH_3)_{3.5}$: NH_3, 12.53. Found: 12.36, 12.40.

---

[24] Roser, *Ber.*, **18**, 805 (1885).

[25] Meyer and Turnau, *Monatsh.*, **30**, 483 (1909).

[26] See Heller, *Ber.*, **28**, 315 (1895). Baeyer, *Ann.*, **183**, 56 (1876). R. and H. Meyer, *Ber.*, **29**, 2624 (1896).

[27] See Heller, *Ber.*, **42**, 2188 (1909).

On standing in an evacuated Hempel desiccator containing cond. sulfuric acid, this salt loses ammonia and comes to constant weight, when $1^1/_2$ molecules of ammonia remain.

Anal. Subs., 0.2234, 0.1929: salt, 0.2364, 0.2044. Calc. for $C_{14}H_8Br_2O_5 + (NH_3)_{1.5}$: NH_3, 5.79. Found: 5.50, 5.62.

When the substance is heated at 85° in a current of dry air the remaining $1^1/_2$ molecules of ammonia are driven off.

Tri-acetate of the Dibromo Acid.—Five g. of the dibromo acid was boiled with an equal weight of fused sodium acetate and 35 cc. of acetic anhydride for two hours. The mixture was poured into cold water, the acetyl derivative precipitating as a brown oily solid. It was crystallized twice from alcohol, giving colorless needles; m. p., 179–182°. Recrystallization from methyl alcohol did not change the melting point. A sample, dried at 120°, was analyzed.

Anal. Subs., 0.2019, 0.2015: AgBr, 0.1388, 0.1390. Calc. for $C_{14}H_5Br_2O_5(C_2H_3O)_3$: Br, 29.49. Found: 29.27, 29.38.

These analyses show that the substance is the *tri-acetate* of 3,5-dibromo-2,4-dihydroxybenzoyl-*o*-benzoic acid. It is very soluble in hot methyl alcohol, absolute alcohol, benzene, glacial acetic acid and ethyl acetate, not very soluble in these solvents when cold; difficultly soluble in ether; insoluble in water. It is insoluble in cold sodium hydroxide solution, but is readily saponified giving the dibromo acid when boiled with an alcoholic sodium hydroxide solution in which it dissolves to form a yellow liquid. The formula of the tri-acetate is similar to that of the tri-acetate of the dihydroxy acid.

Anhydride of the Mono-acetate of the Dibromo Acid.—Five g. of the dibromo acid was boiled for two hours with 35 cc. of acetic anhydride. After some of the anhydride had been distilled, colorless crystals separated from the solution. They were purified by boiling with anhydrous ether, in which they are insoluble. The product thus obtained is a white, crystalline powder that melts at 200–201°, with decomposition. The following analyses show that the substance is the anhydride of the mono-acetate of 3,5-dibromo-2,4-dihydroxybenzoyl-*o*-benzoic acid.

Anal. Subs., 0.1988, 0.2221: AgBr, 0.1696, 0.1878. Calc. for $C_{14}H_5Br_2O_4(C_2H_3O)$: Br, 36.32. Found: 36.31, 35.99.

Subs., 0.2012, 0.1999, 0.2004: 5.47, 5.36, 5.32 cc. net of 0.1 *N* NaOH; 0.89, 0.92, 0.78 cc. of 0.1 *N* iodine. Calc. for $C_{14}H_5Br_2O_4(C_2H_3O)$: C_2H_3O, 9.78. Found: 9.78, 9.55, 9.73.

The compound is very soluble in ethyl acetate and benzene; soluble in hot ethyl alcohol, hot glacial acetic acid and hot methyl alcohol; insoluble in water, ether and cold methyl and ethyl alcohols. When crystallized from dil. acetic acid it melted at 218°, with decomposition, forming probably the mono-acetate of the dibromo acid analogous to the formation of the mono-acetate of the dihydroxy acid from its anhydride. It dissolves in concd. ammonium hydroxide and cold sodium hydroxide solution giving a yellow liquid, the dibromo acid being precipitated when the latter solution is acidified. This was proved by an analysis of the purified saponification product.

Anal. Subs., 0.1992, 0.2006: AgBr, 0.1805, 0.1821. Calc. for $C_{14}H_8Br_2O_5$: Br, 38.43. Found: 38.56, 38.63.

The structural formula of the anhydride of the mono-acetate of the dibromo acid is similar to that of the anhydride of the mono-acetate of the dihydroxy acid already given.

Diacetate of 3,5-Dibromo-2,4-dihydroxybenzoyl-*o*-benzoic Acid Anhydride.[28]—2.5 G. of the dibromo acid was boiled on a water-bath for two hours with 35 cc. of acetyl

---

[28] This work was done by Mr. C. V. Shapiro.

chloride. The solution was set aside overnight, causing the red amorphous material which first separated to redissolve, and then distilled to one-half its original volume. On cooling, the mass set to crystals which were purified by recrystallization from glacial acetic acid and then from absolute alcohol, giving colorless crystals melting at 218°. Further recrystallization from ether did not change the melting point. The following analyses on the product indicate that it is the diacetate of dibromo-dihydroxybenzoylbenzoic acid anhydride.

Anal. Subs., 0.1833, 0.1366: AgBr, 0.1531, 0.1146. Subs., 0.1516, 0.2553: 3.41, 5.52 cc. net of 0.1 *N* NaOH. Calc. for $(C_{14}H_6Br_2O_4)_2O(C_2H_3O)_2$: Br, 35.60; C_2H_3O, 9.58. Found: Br, 35.55, 35.70; C_2H_3O, 9.68, 9.30.

The diacetate is readily soluble in glacial acetic acid, absolute alcohol and ether. It dissolves in cold 5% sodium hydroxide solution forming a yellow liquid, and when this solution is acidified the dibromo acid is precipitated.

Summary

1. 2,4-Dihydroxybenzoyl-*o*-benzoic acid has been prepared by heating resorcinol and phthalic anhydride alone, without a condensing agent and shown to be identical with the acid formed by decomposing fluorescein with strong sodium hydroxide solution. It crystallizes from water in *colorless* needles containing a molecule of water. The anhydrous acid melts at 208–209° with decomposition.

2. The formation of fluorescein by heating the dihydroxy acid under various conditions has been investigated. Liebig's γ-fluorescein, $(C_{20}H_{12}O_5)_4+H_2O$, could not be obtained.

3. The tri-ammonium, mono-ammonium, sodium, potassium, silver, barium, calcium, zinc and lead salts of the acid have been prepared and studied. Baeyer's statement[2] that crystallized salts of this acid could not be prepared is incorrect.

4. The *tri-acetate* of the dihydroxy acid has been prepared by heating the acid with acetic anhydride and sodium acetate. Liebig's statement that it is a *diacetate* is incorrect.[4]

5. The anhydride of the mono-acetate of dihydroxybenzoyl-benzoic acid is formed by the action of acetic anhydride alone on the dihydroxy acid. When this substance is crystallized from dil. acetic acid it takes up a molecule of water and forms the mono-acetate of the dihydroxy acid.

6. The diacetate of dihydroxybenzoyl-benzoic anhydride has been prepared and its saponification product shown to be an anhydride of the dihydroxy acid.

7. The action of thionyl chloride on the dihydroxy acid has been investigated and the product formed shown to be identical with the anhydride made by the saponification of the diacetate of dihydroxybenzoylbenzoic anhydride. Graebe's anhydride[7] was not obtained.

8. The methyl and ethyl esters of the dihydroxy acid have been made by the catalytic method of esterification. They are probably normal carboxylic esters.

9. 2,4-Dimethoxybenzoyl-*o*-benzoic acid, its methyl ester and ammonium salt have been made from the dihydroxy acid.

10. The phenylhydrazone of dihydroxybenzoyl-benzoic acid has been prepared.

11. 3,5-Dibromo-2,4-dihydroxybenzoyl-*o*-benzoic acid and its tri-acetate have been prepared and studied. The action of dry ammonia gas on the dibromo acid and the formation of eosin by heating the acid have been investigated.

12. The anhydride of the mono-acetate of dibromo-dihydroxybenzoyl-benzoic acid has been prepared.

13. The diacetate of the anhydride of the dibromo acid has been prepared.

14. This investigation confirms the theory that the formation of fluorescein (like that of other phthaleins) takes place in two stages and that 2,4-dihydroxybenzoyl-*o*-benzoic acid is the intermediate product.

ITHACA, NEW YORK

[CONTRIBUTION FROM THE LABORATORY OF ORGANIC CHEMISTRY OF THE UNIVERSITY OF WISCONSIN]

ORGANIC REACTIONS AT THE SURFACES OF DEHYDROGENATING CATALYSTS

BY HOMER ADKINS AND WILBUR A. LAZIER

RECEIVED MAY 31, 1924 PUBLISHED OCTOBER 4, 1924

In considering the causation of organic reactions it has seemed advisable to investigate experimentally the behavior of representative organic compounds at the surfaces of those catalysts whose most pronounced characteristic is to remove hydrogen from the organic molecule. In particular, an attempt is being made to correlate the dehydrogenating and the hydrogenating power of a catalyst. Since it has been recently demonstrated[1] that the relative proportion of reactions taking place at the surface of alumina and titania are quite dependent upon physical characteristics of the surface, it seemed desirable to find out whether the reactions taking place with nickel, copper, iron and zinc catalysts were similarly dependent or were characteristic of the metal present. To this end the behavior of ethanol, ethyl acetate, acetal, ether, acetaldehyde and acetic acid at the surfaces of various catalysts containing these metals has been investigated, as has the hydrogenation of ethylene over nickel. The data accumulated are so extensive that only an abstract of them can be presented. While possibly there is no relationship between mass and trustworthiness of data, it should be pointed out that the conclusions given in this paper are based

---

[1] Adkins and Nissen, THIS JOURNAL, **46**, 130 (1924).