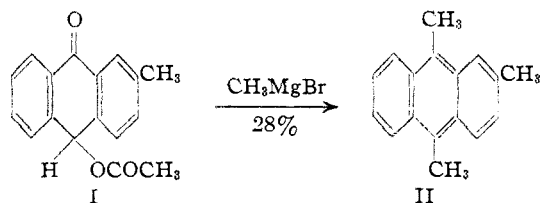


[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF HARVARD UNIVERSITY]

## Reaction of Grignard Reagents with Acyloxyanthrones

BY LOUIS F. FIESER AND HANS HEYMANN

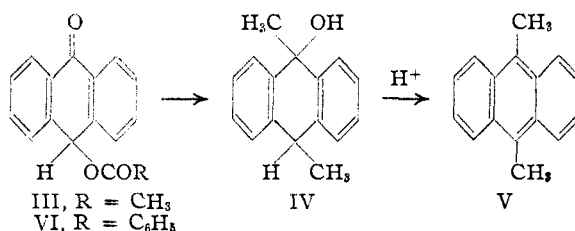
In the course of synthetic work previously reported,<sup>1</sup> it was found that the meso-methylation of 2-( $\gamma$ -carboxypropyl)-anthrone-9 by the Grignard reaction proceeds only very poorly, probably because of the tendency of the anthrone to enolize. With the thought that the yield in this type of operation might possibly be improved by the use of the acyloxyanthrone, we investigated as a model case the reaction of excess methyl Grignard reagent with 2-methyl-10-acetoxyanthrone-9 (I). The reaction took a wholly unexpected course and afforded a significant amount of the known 2,9,10-trimethylantracene (II),<sup>2</sup> along with an



approximately equal amount (27%) of  $\beta$ -methyl-anthraquinone. It was observed that this quinone combines with the hydrocarbon in the molecular ratio 2:1 to form a bright red crystalline complex.<sup>3</sup> Meso-alkyl groups appear to be essential for this type of complex formation, for anthracene itself gives no coloration when added to a solution of anthraquinone or  $\beta$ -methyl-anthraquinone, whereas a solution of II and  $\beta$ -methyl-anthraquinone is dark red and a solution of 9,10-dimethylantracene and anthraquinone also shows a red color and affords a red solid. It is of interest that the picrates and trinitrobenzene complexes of meso-dialkylantracenes, meso-alkyl-1,2-benzanthracenes, and cholanthrenes are much more highly colored than those of anthracene or 1,2-benzanthracene derivatives having no meso substituents.

The formation of a hydrocarbon instead of an anthranol derivative in the Grignard reaction seemed so unusual and interesting that the original objective was set aside and a study made of the new reaction. From 10-acetoxyanthrone-9 (III), by interaction with excess methylmagne-

sium bromide, 9,10-dimethylantracene could be obtained in 55–58% yield with anthraquinone as the only by-product. When the Grignard complex was decomposed with ammonium chloride



rather than with acid the product isolated was colorless, had the composition of 9,10-dimethyl-9,10-dihydroanthranol (IV), and underwent dehydration to the yellow hydrocarbon (V) under the influence of a trace of mineral acid. The course of the Grignard reaction was the same whether excess methyl bromide was present or not, and hence there can be no analogy to the C-alkylation of anthrone with an alkyl halide and alkali observed by K. H. Meyer.<sup>4</sup> The removal of residual traces of magnesium metal by careful filtration likewise did not alter the results. The reaction of III with phenylmagnesium bromide afforded 9,10-diphenylantracene.

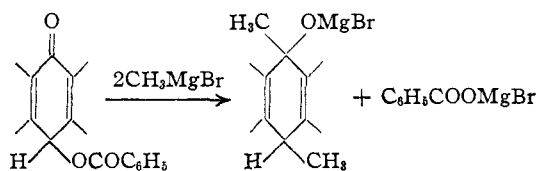
The interaction of the Grignard reagent with the ester in question thus does not result in the usual cleavage to the hydroxy compound but in the replacement of the acyloxy group by an alkyl radical. As a means of determining if the acyloxy group is split off as such or only after an addition of the reagent to the carbonyl group of the acyloxy radical, the behavior of 10-benzoyloxyanthrone-9 (VI) was investigated. Treatment of this ester with 7 equivalents of methylmagnesium chloride resulted in the production of both benzoic acid and dimethylphenyl carbinol, but since magnesium benzoate is known to react with the Grignard reagent<sup>5</sup> the formation of the latter substance may have been associated with the use of a very large excess of reagent. Unfortunately an excess of reagent amounting to 3–5 equivalents has been found necessary in order to obtain satisfactory yields in the Grignard alkyla-

(1) Fieser and Heymann, *THIS JOURNAL*, **63**, 2333 (1941).(2) Bachmann and Chemerda, *J. Org. Chem.*, **4**, 583 (1939).

(3) Complexes from benzoquinones and hydrocarbons are described by P. Pfeiffer, "Organische Molekülverbindungen," F. Enke, Stuttgart, 1922, p. 204.

(4) K. H. Meyer, *Ann.*, **379**, 37 (1911).(5) Farbenfab. F. Bayer, German Patent 166,898 (1905); *Friedländer*, **8**, 1292 (1907).

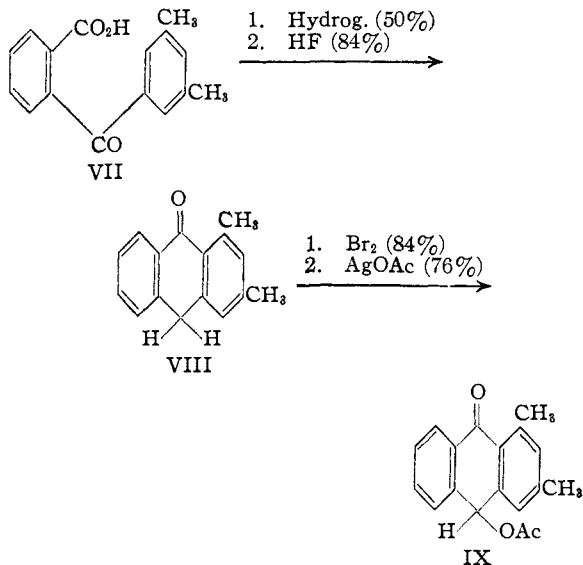
tion of anthrone,<sup>6</sup> and even so some of the material is diverted from the reaction by enolization. Some enolization of VI to anthrahydroquinone monobenzoate was observed in the present case, but it was found that the benzoic acid produced can be extracted from the mixture with sodium carbonate solution without hydrolyzing this ester. The best results were obtained with two moles of methylmagnesium bromide per mole of VI, under which conditions there was isolated 25% of 9,10-dimethylantracene as the picrate and 41% of benzoic acid. That the yield of the hydrocarbon falls short of that of the acid may well be a consequence of the complexity of the mixture and the difficulty in making a quantitative separation of the hydrocarbon from other neutral products, and the fact that a significant amount of benzoic acid was produced suggests that the reaction follows the course



The total change represents attack by the Grignard reagent at two different points. It seems likely that the replacement of the acyloxy group precedes the addition of another mole of reagent to the meso-carbonyl group, but an attempt to secure evidence on this point was unsuccessful. It was thought that a methyl substituent adjacent to the carbonyl group might impede the addition but allow the other reaction to proceed. According to von Braun and Bayer,<sup>7</sup> 1-methylantrone-9 can be prepared by the high-pressure hydrogenation of 1-methylantraquinone, but the substance which we obtained under similar conditions was found by synthesis to be 1-methylantrone-10. A suitable test material, however, was synthesized from 3,5-dimethylphenylmagnesium bromide and phthalic anhydride through the intermediates VII-IX. The reaction mixture from 1,3-dimethyl-10-acetoxyanthrone-9 (IX) and methylmagnesium bromide was complex and difficult to process, and the only products isolated and identified were 1,3-dimethylantraquinone, a small amount of 1,3,9,10-tetramethylantracene, and the anthrone (VIII). The formation of VIII is understandable when one considers that hy-

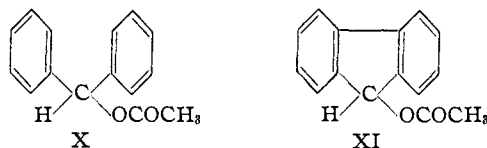
(6) Krollpfeiffer and Branscheid, *Ber.*, **56**, 1617 (1923); Sieglitz and Marx, *ibid.*, **56**, 1619 (1923).

(7) von Braun and Bayer, *ibid.*, **59**, 914 (1926).



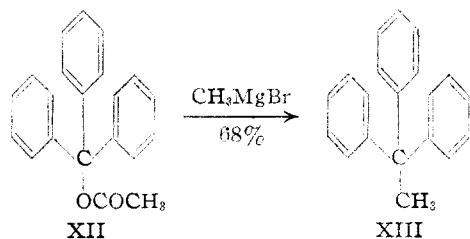
droxyanthrone is known to disproportionate into anthrone and anthraquinone when heated.<sup>4</sup> No 1,3,10-trimethylantrone-9 could be found. In another experiment, the reaction mixture was reduced with zinc dust and alkali and the hydrocarbon mixture fractionated. 1,3-Dimethyl- and 1,3,9,10-tetramethylantracene were isolated, but no trimethyl derivative could be detected.

No analogy to the replacement reaction could be found in the literature. Benzhydryl acetate (X) represents a model of 10-acetoxyanthrone-9 (III) without the bridging carbonyl group, but Stadnikow<sup>8</sup> made a careful investigation of the action of the Grignard reagents on this ester and observed no replacement of the acetoxy group. We investigated the behavior of fluorenyl acetate (XI) as a possibly closer analogy to III, but found that treatment with Grignard reagent resulted



merely in cleavage to fluorenyl. O-Acetylmandelic acid, in which the acetoxy group would be expected to be reasonably labile, reacted similarly and afforded merely 80% of mandelic acid, with no trace of hydratropic acid, and the results were substantially the same with the mesitoyl derivative. Triphenylmethyl acetate (XII), however, afforded  $\alpha,\alpha,\alpha$ -triphenylethane (XIII) in good yield when stirred with a methyl Grignard reagent. This result shows that the replacement of

(8) Stadnikow, *ibid.*, **57**, 1 (1924).



an acetoxy group can occur if the oxygen-substituent is sufficiently activated. The replacement observed in the series of acyloxyanthrones thus appears attributable to the presence of the two adjacent, activating benzenoid nuclei with the reinforcing activation transmitted from the meso-carbonyl group.

### Experimental<sup>9</sup>

**2-Methyl-10-acetoxyanthrone-9 (I).**—Prior to the present work, this compound was obtained by S. T. Putnam of this Laboratory by the oxidation of  $\beta$ -methylanthracene with lead tetraacetate (to be reported). The following method is more convenient for preparative purposes.

A solution of 70 g. of crude 2-(*p*-toluoyl)-benzoic acid<sup>10,11</sup> in alkali was adjusted to neutrality, made up to 200 cc., and shaken with 7 g. of copper chromite catalyst and hydrogen under 1500–2000 lb. pressure at 200°,<sup>12</sup> when the calculated amount of hydrogen was soon consumed. Acidification of the filtered solution, extraction of the precipitate with sodium carbonate solution, and reacidification yielded 63 g. of crude 2-(*p*-methylbenzyl)-benzoic acid,<sup>10</sup> but only 42.9 g. (65%) could be obtained in a crystalline form from dilute ethanol, m. p. 130–134° (pure, 133.6–135.8°). The acid (10 g.) was cyclized with liquid hydrogen fluoride at room temperature (one and one-half hours) and an ethereal solution of the crude product was washed with sodium bicarbonate solution, clarified with Darco, evaporated to beginning crystallization and cooled in ice. This afforded in two crops 7.7 g. (84%) of pure 2-methylanthrone-9, m. p. 102.3–103.8°. The yield is much better than that obtained with the use of sulfuric acid.<sup>10</sup> Bromination of 3 g. of the anthrone according to Barnett and co-workers<sup>13</sup> gave 3.41 g. (83.5%) of 2-methyl-10-bromoanthrone-9, and on employing the mother liquor for a second bromination the yield rose to 92.8%. Crystallization was accomplished by dissolving the compound in benzene at 50° and adding an equal volume of boiling hexane. When introduced to a rapidly heated bath at 125°, the substance decomposed at 133° (varies with the rate of heating). A suspension of 4.6 g. of the bromo compound and 2.7 g. of silver acetate in 240 cc. of glacial acetic acid was shaken for fifteen minutes and, after filtering and washing the precipitated silver bromide, the filtrate was slowly diluted to a volume of 1 liter, when a white crystallize appeared consisting of 3.82 g. (89.5%) of

satisfactory 2-methyl-10-acetoxyanthrone-9, m. p. 112–113.8°. One recrystallization from hexane raised the melting point to 113.4–114.6°.

**Action of Grignard Reagent on 2-Methyl-10-acetoxyanthrone.**—A solution of 3.8 g. of the anthrone in 80 cc. of ether was added to a stirred solution prepared from 2.3 g. of magnesium in 100 cc. of ether and excess methyl bromide, introduced through a drying tube packed with calcium chloride, Ascarite, and Dehydrite; each drop produced an orange precipitate which soon turned yellow. After stirring for twelve hours at room temperature, the mixture was decomposed with dilute acid, the initially green-fluorescent ether layer was dried and concentrated, and the reddish residue dissolved in alcohol. Several crops of a red, nicely crystalline substance were obtained melting in the range 90–140°. A part of the first and particularly pure crop was passed in benzene solution through a column of activated alumina, and from the yellow, blue-violet fluorescent filtrate there was isolated 2,9,10-trimethylanthracene, m. p. 101–101.4°; after solidification the sample remelted at 94.2–96.2° (Bachmann and Chernerda,<sup>2</sup> 100–101°, 95–96°).

A 224-mg. portion of the red material was extracted with successive portions of a hot solution of 1 part each of sodium hydroxide and sodium hydrosulfite in 10 parts of water, and the vat liquors were filtered from a solid residue consisting of 81 mg. (36%) of 2,9,10-trimethylanthracene. Air oxidation of the vat liquors afforded 146 mg. (65%) of  $\beta$ -methylanthraquinone; the calculated composition of a 1:2 complex is 33% hydrocarbon and 67% quinone.

The total hydrocarbon isolated from various crops of the red complex after extraction of an ethereal solution with alkaline hydrosulfite amounted to 900 mg. (28%). An analytical sample crystallized from alcohol in yellow needles, m. p. 95.6–96.6°.

*Anal.* Calcd. for C<sub>17</sub>H<sub>16</sub>: C, 92.68; H, 7.32. Found: C, 92.46, 92.66; H, 7.34, 7.45.

Oxidation of 100 mg. of the hydrocarbon in acetic acid solution with 6 equivalents of chromic anhydride gave, after crystallization from alcohol, 32 mg. of  $\beta$ -methylanthraquinone, m. p. 174–175.8° (identified by mixed m. p.).

**10-Acetoxyanthrone-9<sup>4</sup> (III).**—A mixture of 18 g. of bromoanthrone, prepared according to Meyer<sup>4</sup> and crystallized from benzene-hexane, and 12 g. of silver acetate in 100 cc. of cold acetic acid was shaken for five minutes. The solution was filtered from precipitated silver bromide, treated with Darco, and diluted with water until no more crystalline precipitate separated. The nearly colorless product on recrystallization from 250 cc. of ligroin b. p. 70–90° and 100 cc. of ligroin b. p. 90–120° gave 13.7 g. (83%) of the pure acetoxy compound m. p. 108.8–110.8°.

**Grignard Reaction (a).**—The reagent from 2 g. of magnesium and methyl bromide in 100 cc. of ether was refluxed for twenty minutes to expel excess methyl bromide and treated with a solution of 3 g. of III in 80 cc. of ether. After the suspension of complex had been stirred at room temperature for fifteen hours, water and hydrochloric acid were added and the ether layer was extracted exhaustively with alkaline hydrosulfite with prolonged shaking. Air oxidation of the vat liquor gave 1.0 g. (40.5%) of anthra-

(9) All melting points are corrected.

(10) Limpricht, *Ann.*, **314**, 237 (1901); Barnett and Goodaway, *J. Chem. Soc.*, 1754 (1929).

(11) Barnett and Mathews, *Ber.*, **59**, 1429 (1926).

(12) Method of Ref. 1.

(13) Barnett, Low and Morrison, *Ber.*, **64**, 1568 (1931).

quinone. The material recovered from the ether layer was taken up with alcohol, and on the addition of a few drops of concentrated hydrochloric acid 1.42 g. (58%) of the sparingly soluble 9,10-dimethylantracene<sup>11</sup> crystallized. Recrystallization from benzene gave material melting constantly at 183–184.4° and giving no depression when mixed with an authentic sample.

(b).—A solution of 3 g. of III was added to a solution of Grignard reagent which had been filtered free of magnesium particles under nitrogen pressure but not refluxed to remove excess methyl bromide; in other respects the conditions were the same as in (a). The reaction mixture was decomposed with saturated ammonium chloride solution and the anthrahydroquinone present in the ether layer was oxidized by a current of air. The anthraquinone which crystallized amounted to 940 mg. (38%). The dried ether solution, kept basic by the addition of a drop of pyridine, was evaporated under reduced pressure to a volume of 10 cc. and treated with 25 cc. of petroleum ether, when 500 mg. (18.5%) of 9,10-dimethyl-9,10-dihydroanthranol (IV) crystallized. Recrystallization from benzene–ligroin and then twice from dilute methanol, always in the presence of a trace of pyridine, gave faintly yellowish prisms which decomposed and turned yellow at about 125°.

*Anal.* Calcd. for C<sub>16</sub>H<sub>16</sub>O: C, 85.68; H, 7.19. Found: C, 85.50, 85.36; H, 7.38, 7.36.

The residue collected from the mother liquor was dissolved in alcohol and a little hydrochloric acid added to the hot solution; 900 mg. (37%) of 9,10-dimethylantracene promptly crystallized.

(c).—The condensation of 3 g. of IV with the Grignard reagent from 13 g. of bromobenzene was conducted as above, the mixture was decomposed with acid, and anthraquinone (1.65 g., 67%) was separated after aeration. The ethereal solution was evaporated, biphenyl was removed with steam, and the residue was boiled with acetic anhydride (4 cc.) and pyridine (3 cc.).<sup>11</sup> The dark solution on cooling deposited 320 mg. (8%) of 9,10-diphenylanthracene<sup>11,14</sup> in the form of yellow prisms, m. p. 230–240°, and 150 mg. (4%) more was recovered from the mother liquor, m. p. 225–235°. The first crop, when recrystallized from benzene and then from benzene–acetic acid, formed pale yellow prisms which melted at 250–252° and remelted, after solidification, at 251.5–252.5°. When introduced to a bath at 249°, the substance melted immediately, resolidified and remelted at the higher temperature (lit.<sup>11,14</sup> 241–243°, uncor.).

*Anal.* Calcd. for C<sub>26</sub>H<sub>18</sub>: C, 94.51; H, 5.49. Found: C, 94.19; H, 5.75.

**10-Benzoyloxyanthrone-9 (VI).**—A suspension of 24.6 g. of bromoanthrone and 21 g. of recrystallized and powdered silver benzoate in 500 cc. of benzene was shaken for fifteen minutes and the resulting pink solution was filtered from silver bromide and evaporated under reduced pressure until crystals appeared. The material was brought into solution again and, after dilution with hexane, 21.2 g. of material crystallized consisting chiefly of long needles but containing a few crystals of a prismatic modification of the benzoate; both forms melted at 122–129°. With a second crop of 1.2 g., the total yield of crude product was 80.5%.

A small amount of a high-melting impurity was removed only after several recrystallizations from ligroin (90–120°), and the yield of satisfactory material was only 11.8 g. (41.5%). The best sample melted at 130.6–131.8°.

*Anal.* Calcd. for C<sub>21</sub>H<sub>14</sub>O<sub>3</sub>: C, 80.24; H, 4.49. Found: C, 80.37; H, 4.74.

**Grignard Reaction (a).**—The reaction mixture of 2.28 g. of VI in ether–benzene and the Grignard reagent from 1.22 g. of magnesium and methyl chloride was stirred at room temperature for ten hours, refluxed for one-half hour, and decomposed with water and acid. Extraction of the organic layer with 1.6% sodium carbonate gave 100 mg. (11%) of benzoic acid, and a further extraction with alkaline hydrosulfite afforded, after oxidation, 410 mg. (25%) of anthraquinone. The oily residue from the ether after digestion with alcohol yielded a crystallate (750 mg., 50%) of 9,10-dimethylantracene, m. p. 178–181°, and from the mother liquor there was isolated a small amount of dimethylphenyl carbinol, b. p. 82–83° (8 mm.), m. p. 25–28°.

(b).—From a similar reaction conducted for forty hours at room temperature with 10 g. of VI and 2.75 equivalents of methylmagnesium bromide, there was isolated by extraction with sodium bicarbonate 495 mg. (13%) of benzoic acid; sodium carbonate removed no more acidic material. On subsequent extraction with alkaline hydrosulfite, yellow crystals of anthrahydroquinone monobenzoate appeared in the aqueous layer. This was dissolved in cold dilute alkali and the yellow solution (red when heated) was acidified quickly, giving 750 mg. (7.5%) of the monobenzoate (no definite m. p.). A sample was shaken with benzoyl chloride and alkali and the precipitated product was freed from anthraquinone formed in the process by vating and crystallized from acetic acid; it melted at 302–304° and did not depress the melting point of authentic anthrahydroquinone dibenzoate.

Processing of the vat liquor and the neutral ethereal solution as above afforded anthraquinone (60%) and 9,10-dimethylantracene (9%).

(c).—A reaction mixture of 2.4 g. of VI in ether–benzene and two equivalents of methylmagnesium chloride was stirred at room temperature for one and one-half hours. After hydrolysis, extraction with 2% sodium carbonate solution yielded 380 mg. (41%) of benzoic acid. Anthraquinone (490 mg., 31%) was then extracted as above, and the residual oil, which largely solidified, afforded a total of 830 mg. (25%) of crude 9,10-dimethylantracene picrate; after recrystallization this melted at 175–176.5°.

**2-(*o*-Methylbenzyl)-benzoic Acid.**—The starting material, 2-(*o*-methylbenzoyl)-benzoic acid, was obtained according to Scholl and Donat<sup>15</sup> in slightly improved yield by carrying out the condensation of the Grignard reagent from *o*-bromotoluene (80 g.) and phthalic anhydride (62 g.) in a nitrogen atmosphere. The yield of product melting at 129.6–132.6° was 74.5 g. (74%). The acid crystallized well from either xylene<sup>15</sup> or 30% acetic acid. The material from the first run tended to crystallize in hair-like needles, m. p. 110–115°, but once the high melting prismatic form had been secured it always could be caused to crystallize by seeding.

For reduction, a neutralized solution of 3 g. of the keto

(14) Haller and Guyot, *Compt. rend.*, **138**, 1253 (1904).

(15) Scholl and Donat, *Ber.*, **64**, 318 (1931).

acid in dilute alkali was shaken with 300 mg. of copper chromite catalyst at 225° under 2600 lb. initial hydrogen pressure for five hours. The yield of crude product, m. p. 126–129.5°, was 2.64 g. (93.5%). After two recrystallizations from 50% acetic acid the substance formed small hexagonal prisms, m. p. 128–131°.

*Anal.* Calcd. for  $C_{15}H_{14}O_2$ : C, 79.62; H, 6.23. Found: C, 79.84; H, 6.36.

**4-Methylanthrone-9.** (a) **By Synthesis.**—A solution of 1.66 g. of the foregoing acid in 50 g. of liquid hydrogen fluoride was allowed to stand for one and one-quarter hours, drowned, and an ethereal solution of the collected product was washed with bicarbonate solution, decolorized with Darco, dried and evaporated. Crystallization of the residue from 400 cc. of ligroin (90–120°) gave 1.18 g. (77%) of large colorless prisms of the anthrone, m. p. 128–129.5°. The anthrone crystallized from alcohol in needles, m. p. 125.5–129.5°, which slowly changed to the prismatic form on standing in contact with the solvent.

*Anal.* Calcd. for  $C_{14}H_{12}O$ : C, 86.50; H, 5.80. Found: C, 86.31; H, 5.92.

The acetate, prepared with acetic anhydride in pyridine, crystallized from dilute alcohol in colorless, weakly blue-fluorescent needles which melted over the range of 92–95.5° even after repeated recrystallizations.

*Anal.* Calcd. for  $C_{17}H_{14}O_2$ : C, 81.58; H, 5.64. Found: C, 81.65; H, 5.73.

(b) **By Hydrogenation of  $\alpha$ -Methylanthraquinone.**—Contrary to the report of Scholl and Donat,<sup>15</sup> the cyclization of 2-(*o*-methylbenzoyl)-benzoic acid to  $\alpha$ -methylanthraquinone was found to proceed best when the acid was heated in 10-g. portions with 40 cc. of concentrated sulfuric acid for one hour on the steam-bath. The precipitated product from three portions was washed, slurried with 3 g. of sodium carbonate in 1 liter of water, and collected; yield 26.9 g. (97%), m. p. 169.5–171.5°. Recrystallized from acetic acid containing a trace of chronic anhydride the quinone melted at 171–173.4°.

A hydrogenation bomb was charged with 3 g. of the quinone, 300 mg. of copper chromite catalyst, and 8 cc. of absolute ethanol; slightly more than the calculated amount of hydrogen was admitted, and nitrogen was passed in to make up a total pressure of 1000 lb. At 150°, 20% of the calculated amount of hydrogen was soon consumed and then the reaction came to a stop and failed to proceed on raising the temperature to 170°. On admission of hydrogen to the total pressure of 1800 lb., the consumption of hydrogen reached two equivalents in one and one-half hours, but no end-point was observed. The reaction mixture afforded 1.39 g. (49.5%) of 4-methylanthrone-9 in three crops of yellowish prisms which, after recrystallization from ligroin, melted at 127–129.5° and did not depress the m. p. of the other sample (a). Our product corresponds to that obtained by von Braun and Bayer (m. p. 126–127°); although they state that their substance yielded no acetyl derivative and hence probably was 1-methylanthrone-9, it is to be noted that the comparably hindered 1,3-dimethylanthrone-9 was acetylated satisfactorily by Barnett and Hewett.<sup>16</sup>

In an attempted hydrogenation with the catalyst<sup>17</sup> and

(16) Barnett and Hewett, *Ber.*, **64**, 1572 (1931).

(17) von Braun, *Chem. Zentr.*, **101**, II, 3852 (1930).

under conditions specified by von Braun and Bayer,<sup>7</sup> the calculated amount of hydrogen was consumed in less than five minutes and the reaction mixture was an oil. Reduction of the quinone with tin and hydrochloric acid in acetic acid solution gave 6.5% of 4-methylanthrone-9 as the only crystalline product isolated.

***o*-(3,5-Dimethylbenzoyl)-benzoic acid (VIII).**—In preparing 1,3,5-dimethylbromobenzene according to E. Fischer and Windaus,<sup>18</sup> *as-m*-xylydine was purified through its acetate salt<sup>19</sup> (acetyl derivative of the purified base, m. p. 127–129°) and the crude 1,3-dimethyl-4-amino-5-bromobenzene hydrochloride resulting from the bromination of two 121-g. portions of amine was purified by dissolving it in 500 cc. of hot water containing 10 cc. of concentrated hydrochloric acid, and clarifying the solution with Darco. On cooling there separated 319 g. (67%) of slightly pink needles, and recrystallization in the presence of about 1% of stannous chloride gave 286 g. (60%) of colorless crystals of the salt.

Sodium stannite proved to be a more satisfactory reagent for deamination than alcohol.<sup>18</sup> A suspension of 23.5 g. of the above salt in 60 cc. of water and 15 cc. of concentrated hydrochloric acid was diazotized at 5° with 7 g. of sodium nitrite in 30 cc. of water and the solution was added in portions to an ice-cold mixture of 40 g. of stannous chloride crystals in 200 cc. of water with a solution of 50 g. of sodium hydroxide in 60 cc. of water. Steam distillation of the reaction mixture gave 1,3,5-dimethylbromobenzene as a light yellow liquid, and the yield of colorless product, b. p. 88–89° (12 mm.) was 13.2 g. (73%). The results were essentially the same when the diazonium salt solution was made alkaline before reduction, but the yield dropped when the stannite solution was run into the solution of the diazotized amine.

The Grignard reagent from 65 g. of the bromo compound and 9.6 g. of magnesium in 130 cc. of ether was added in the course of about two hours to a stirred, ice-cold suspension of 46.5 g. of phthalic anhydride in 220 cc. of benzene and 95 cc. of ether. Stirring was continued for one hour at room temperature and for one and one-half hours at the reflux temperature. After hydrolysis and steam distillation, the product was suspended in 800 cc. of 2% sodium hydroxide and submitted to steaming; the material precipitated from the filtered yellow solution was extracted with sodium carbonate solution (Norit) and obtained as a yellowish powder (49 g.) which, on crystallization from xylene yielded 38 g. (47.5%) of needles which softened at 168° and melted at 175.5–178.5°. Four recrystallizations gave colorless, rectangular needles of *o*-(3,5-dimethylbenzoyl)-benzoic acid, melting constantly at 178.2–180.2°.

*Anal.* Calcd. for  $C_{16}H_{14}O_3$ : C, 75.57; H, 5.55. Found: C, 75.81; H, 5.70.

The acid separates from aqueous acid in the form of large rhombic plates of a hydrate which loses water at 148° and melts at 178°.

***o*-(3,5-Dimethylbenzyl)-benzoic Acid.**—High pressure hydrogenation of 34.5 g. of VII in neutral aqueous solution at 200° gave a reaction product not completely soluble in sodium carbonate solution. After filtration from the slimy

(18) E. Fischer and Windaus, *Ber.*, **33**, 1973 (1900).

(19) Limpach, German Patent 39,947 (1886); *Friedländer*, **1**, 19 (1888).

residue, the acidic material was precipitated and crystallized from benzene, giving a cake of hair-like needles. Recrystallization from acetic acid yielded 15.6 g. (50%) of colorless needles, m. p. 148.2–150.2°.

*Anal.* Calcd. for  $C_{16}H_{16}O_2$ : C, 79.97; H, 6.71. Found: C, 80.07; H, 6.84.

**1,3-Dimethyl-10-acetoxanthrone-9 (IX).**—The above acid (15 g.) was cyclized with hydrogen fluoride; the bicarbonate-washed ethereal solution of the product when concentrated and cooled in ice deposited 12.0 g. (86%) of 1,3-dimethylantrone-9, in the form of colorless needles m. p. 116.5–118.5°; a second crop of pinkish material amounted to 0.9 g. (7%). A sample recrystallized from hexane-ethyl acetate melted at 117–119° and gave an acetyl derivative, m. p. 150–152.5°. These constants are in agreement with the data reported by Barnett and Hewett,<sup>16</sup> who prepared the anthrone by a different method.

A suspension of 5 g. of 1,3-dimethyl-10-bromoanthrone-9<sup>16</sup> and 3.5 g. of silver acetate in 50 cc. of acetic acid was shaken for five minutes and the product, collected as above, was crystallized from hexane, giving 3.55 g. (76%) of the acetoxy compound in the form of white needles, m. p. 107–108.5°.

*Anal.* Calcd. for  $C_{15}H_{16}O_3$ : C, 77.12; H, 5.75. Found: C, 77.11; H, 5.87.

**Grignard Reaction (a).**—The reaction of 3.9 g. of IX with the reagent from 2.4 g. of magnesium and methyl bromide was conducted as above, with refluxing for one-half hour. After concentration of a washed and dried ethereal solution of the reaction mixture to a volume of 40 cc., 960 mg. (29%) of crude 1,3-dimethylanthraquinone<sup>20</sup> crystallized (identified by conversion to the hydrocarbon). Further evaporation afforded 110 mg. (3%) more of the quinone, and the residue was a reddish oil. This was reduced with copper-activated zinc and alkali in the presence of toluene according to Martin<sup>21</sup> and the hydrocarbon mixture was passed through a tower of alumina in benzene solution. Fractionation from alcohol afforded a small amount of 1,3-dimethylantracene,<sup>20,22</sup> m. p. 78.2–79.6°, which yielded 27 mg. of the purified picrate, m. p. 132–133.5°; this gave no depression when mixed with a comparison sample, m. p. 131.5–133°, obtained from the 1,3-dimethylantracene, m. p. 79.5–80°, prepared in 74% yield from the quinone by Martin's method.<sup>20</sup> Another fraction on treatment with picric acid yielded a few milligrams of 1,3,9,10-tetramethylantracene picrate, which when purified formed black needles, m. p. 136.5–138°.

*Anal.*<sup>23</sup> Calcd. for  $C_{24}H_{24}O_7N_3$ : C, 62.20; H, 4.56. Found: C, 61.98; H, 4.65.

(b) In a comparable experiment with 2.5 g. of IX the reaction mixture was stirred overnight at room temperature, and the ethereal solution of the reaction mixture was extracted with alkaline hydrosulfite solution and afforded 800 mg. of crude 1,3-dimethylanthraquinone. The residual organic layer on evaporation left a reddish oil which largely solidified when digested with ligroin (70–90°). Recrystal-

lization from aqueous acetone and then from ligroin afforded 1,3-dimethylantrone-9, identified in the form of the acetate, m. p. 151–152.5° (35 mg.).

The material recovered from the ligroin mother liquor when treated with picric acid in alcohol gave a total of 610 mg. (15%) of crude 1,3,9,10-tetramethylantracene picrate. A 100-mg. sample of purified material, m. p. 136.5–138°, was dissolved in ether and extracted with 10% alkali and the recovered hydrocarbon was crystallized from alcohol (Darco). The crystallate was combined with material obtained from a second crop by sublimation at 100° (1 mm.) and recrystallized from alcohol. The blue-violet fluorescent solution deposited 20 mg. of faintly greenish yellow plates of 1,3,9,10-tetramethylantracene, m. p. 85–87°.

*Anal.* Calcd. for  $C_{18}H_{18}$ : C, 92.26; H, 7.74. Found: C, 92.10; H, 7.81.

**Grignard Reaction with Fluorenyl Acetate.**<sup>24</sup>—The reaction mixture from 4.5 g. of the acetate and 6 equivalents of methylmagnesium bromide was refluxed for one and one-half hours and allowed to stand overnight. Crystallization of the product from benzene gave nicely crystalline solvated material which, when dried to constant weight in vacuum at 100°, afforded 3.28 g. (89.5%) of fluorenyl, m. p. 151–152.6°.

**Grignard Reactions with Acyl Derivatives of Mandelic Acid.**—Treatment of 4 g. of O-acetylmandelic acid<sup>25</sup> with 2 equivalents of methylmagnesium bromide resulted in the recovery of 2.52 g. (80.5%) of mandelic acid.

For the preparation of O-mesitylmandelic acid, 2 g. of the acid was warmed with 2.7 g. of mesityl chloride for one hour on the steam-bath. The resulting solid cake was dissolved in 65 cc. of 55% acetic acid, and the solution deposited 3.05 g. (74%) of colorless blades, m. p. 162–168°. After repeated recrystallizations the substance melted constantly over the range 166–169.8°.

*Anal.* Calcd. for  $C_{15}H_{15}O_4$ : C, 72.47; H, 6.08. Found: C, 72.28; H, 6.25.

The reaction mixture from 3.05 g. of the mesitoate and 2.5 equivalents of methylmagnesium bromide was allowed to stand overnight and then decomposed. The soda-soluble fraction (1.5 g.) when extracted with hot water yielded 0.3 g. (19%) of mesitoic acid, m. p. 151–153.5°, and the undissolved residue (1.06 g., 34%) consisted of unreacted O-mesityl derivative (recrystallized, m. p. 166–169°). The neutral fraction was oily and yielded no solid on treatment with 3,5-dinitrobenzoyl chloride.

**Grignard Reaction with Triphenylmethyl Acetate.**<sup>26</sup>—The addition of the methylmagnesium bromide solution from 1.2 g. of magnesium to an ethereal solution of 3 g. of the acetate produced a white precipitate; the suspension was stirred for eight hours and decomposed with water and acid. The bicarbonate-washed and dried ethereal solution on evaporation left 2.60 g. of a light yellow oil which soon solidified. Distillation at 205–210° (18 mm.) and crystallization from alcohol (Darco) gave, in the first crop, 1.57 g. (61%) of  $\alpha,\alpha,\alpha$ -triphenylethane in the form of colorless needles, m. p. 93.8–95°; a second crop, m. p. 92–94°, amounted to 0.2 g. (8%). The substance did not depress

(20) Gresly, *Ann.*, **234**, 234 (1886); Elbs and Günther, *J. prakt. Chem.*, **41**, 1 (1890).

(21) Martin, *This Journal*, **58**, 1438 (1936).

(22) von Braun and Bayer, *Ber.*, **59**, 914 (1926).

(23) Microanalysis by Lyon Southworth.

(24) Kuhn and Wassermann, *Ber.*, **58**, 2230 (1925).

(25) Thayer, "Organic Syntheses," Coll. Vol. I, 1932, p. 12.

(26) Gomberg, *Ber.*, **35**, 1835 (1902).

the melting point of a sample of the hydrocarbon prepared according to Gomberg.<sup>27</sup>

### Summary

The reaction of a methyl Grignard reagent with substances of the type of 10-acetoxyanthrone-9 results in the replacement of the acetoxy group by an alkyl radical, as well as addition to the carbonyl group, with the eventual production of

(27) Gomberg, *Ber.*, **39**, 2963 (1906).

9,10-dimethylantracene. This apparently novel replacement reaction of acyloxyanthrones seems to be attributable to the special reactivity of the acyloxy group, and an analogy has been found in the smooth reaction of triphenylmethyl acetate with methylmagnesium bromide to give  $\alpha, \alpha, \alpha$ -triphenylethane.

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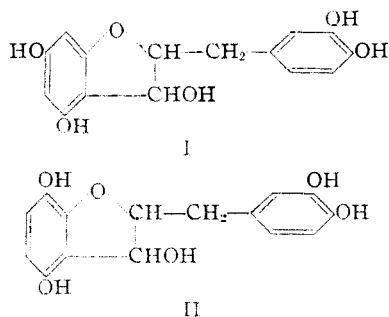
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[CONTRIBUTION FROM THE NOYES CHEMICAL LABORATORY, UNIVERSITY OF ILLINOIS]

## Coumaran Derivatives. IX. Synthesis of 3,4,6,3',4'-Pentahydroxy-2-benzylcoumaran

BY R. L. SHRINER<sup>1</sup> AND FREDERICK GROSSER

From a study of the degradation products of quebracho tannin, Nñez<sup>2</sup> suggested that the tannin was a mixture of 3,4,6,3',4'-pentahydroxy-2-benzylcoumaran (I) and 3,4,7,3',4'-pentahydroxy-2-benzylcoumaran (II). These structures



differ markedly from those suggested by other investigators<sup>3</sup> for the tannins in quebracho and also from the general structure of phlobatannins<sup>4</sup> to which class quebracho belongs. The above structures also differ from fisetin, ellagic acid and gallic acid which Perkin and Gunnell<sup>5</sup> isolated from quebracho.

The present report describes the synthesis of a compound with structure I and its comparison with some of the fractions obtained from quebracho powder.

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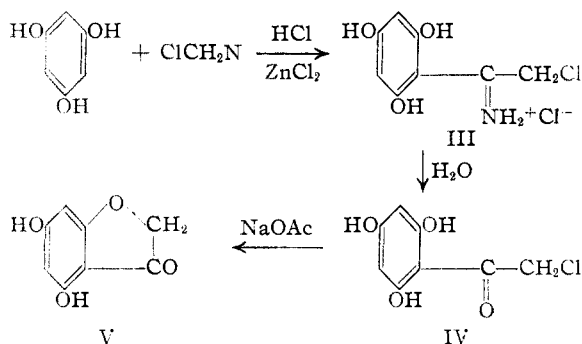
(2) Nñez, *Annales Assoc. Chim. Argentina*, **24**, 159 (1936).

(3) Arata, *Ann. Socied. Cientif. Argentina* (1878), (1879); Franke, *Pharm. Zentr.*, **47**, 887 (1906); Körner and Pertermann, *Deut. Gerbzeit.*, no. 117 (1904); Nierenstein, *Ber.*, **40**, 4575 (1907); *Collegium*, **69** (1905), 141 (1906); Einbeck and Jablonski, *Ber.*, **54**, 1084 (1921); **56**, 1906 (1923); Freudenberg and Maitland, *Ann.*, **510**, 193 (1934).

(4) Russell, *Chem. Rev.*, **17**, 155 (1935).

(5) Perkin and Gunnell, *J. Chem. Soc.*, **69**, 1303 (1896).

A Hoesch<sup>6</sup> reaction between phloroglucinol and chloroacetonitrile produced 2,4,6-trihydroxyphenyl chloromethylketimide hydrochloride (III), which readily hydrolyzed to 2,4,6-trihydroxy- $\alpha$ -chloroacetophenone (IV). Ring closure by treatment with sodium acetate<sup>7</sup> produced 4,6-dihydroxycoumaran-3-one (V). Attempts to condense



4,6-dihydroxycoumaran-3-one with protocatechuic aldehyde did not yield definite crystalline products. However, the dibenzoate (VI) of the coumaran and of protocatechuic aldehyde (VII) readily condensed to give an excellent yield of 4,6,3',4'-tetrabenzoyloxy-2-benzal-coumaran-3-one (VIII). Catalytic reduction with hydrogen and platinum oxide-platinum black at 25° and 4 atmospheres pressure produced a compound which analyzed for 4,6,3',4'-tetra-benzoyloxy-2-benzylcoumaran-3-ol (IX). Saponification with alkali in a nitrogen atmosphere and acidification yielded 3,4,6,3',4'-pentahydroxy-2-benzylcoumaran (I). When compound VIII was reduced in the presence

(6) Hoesch, *Ber.*, **48**, 1122 (1915).

(7) Auwers and Pohl, *Ann.*, **405**, 243 (1914).