

(cor.). Reacetylation of the mixture gave the corresponding acetate, m. p. 144–146° (cor.).

**1 - Hydroxy - 3,9 - dimethyl - 7,8,9,10 - tetrahydro - 6 - dibenzopyrone, X.**—This compound was prepared in essentially the same manner as 1-hydroxy-3-methyl-7,8,9,10-tetrahydro-6-dibenzopyrone. From 6.2 g. of orcinol, 12 g. of ethyl 5-methylcyclohexanone-2-carboxylate, 4.6 cc. of phosphorous oxychloride in 50 cc. of dry benzene was obtained 7.5 g. (62%) of product, m. p. 262–263° (cor.). Chowdry and Desai<sup>4</sup> report a melting point of 260°.

**1 - Hydroxy - 3,6,6,9 - tetramethyl - 7,8,9,10 - tetrahydro-6-dibenzopyran (XI).**—This compound was prepared in the same manner as 1-hydroxy-3,6,6-trimethyl-7,8,9,10-tetrahydro-6-dibenzopyran. From 5.2 g. of magnesium, 12 cc. of methyl iodide and 4.5 g. of 1-hydroxy-3,9-dimethyl-7,8,9,10-tetrahydro-6-dibenzopyrone was obtained 3.7 g. (77%) of the pyran. It was purified by recrystallization from petroleum ether (b. p. 60–110°); white crystals, m. p. 115.5–116° (cor.).

*Anal.* Calcd. for  $C_{17}H_{22}O_2$ : C, 79.04; H, 8.57. Found: C, 78.98; H, 8.75.

**1 - Hydroxy - 3 - n - amyl - 6,6,9 - trimethyl - 7,8,9,10 - tetrahydro-6-dibenzopyran (Tetrahydrocannabinol) XII.**—Prepared from 1-hydroxy-3-n-amyl-9-methyl-6-dibenzopyrone<sup>5</sup> and methylmagnesium iodide, (9 g. of magnesium, 22.5 g. of methyl iodide, and 9 g. of 1-hydroxy-3-n-amyl-9-methyl-7,8,9,10-tetrahydro-6-dibenzopyrone) the product was obtained as a colorless, viscous oil, b. p. 191–192° (1 mm.);  $n_D^{20}$  1.5549; yield 7.3 g. (78%).

*Anal.* Calcd. for  $C_{21}H_{30}O_2$ : C, 80.20; H, 9.62. Found: C, 80.12; H, 9.57.

(5) Adams and Baker, *THIS JOURNAL*, **62**, 2401 (1940).

## Summary

The compound prepared by Desai by condensing ethyl cyclohexanone-2-carboxylate with orcinol has been proved to be 1-hydroxy-3-methyl-7,8,9,10-tetrahydro-6-dibenzopyrone. This was accomplished by dehydrogenation and identification of the 1-hydroxy-3-methyl-6-dibenzopyrone obtained by two methods. The first was by comparing it with a sample of 1-methyl-3-hydroxy-6-dibenzopyrone with which it was not identical. The second was by synthesizing it from *o*-bromobenzoic acid and dihydroorcinol followed by dehydrogenation.

The 1-hydroxy-3-methyl-7,8,9,10-tetrahydro-6-dibenzopyrone with methyl magnesium iodide gives the corresponding pyran, 1-hydroxy-3,6,6-trimethyl - 7,8,9,10 - tetrahydro - 6 - dibenzopyran. By using ethyl 5-methylcyclohexanone-2-carboxylate in place of ethyl cyclohexanone-2-carboxylate, the compound, 1-hydroxy-3,6,6,9-tetramethyl-7,8,9,10-tetrahydro-6-dibenzopyran is produced.

By condensing ethyl 5-methylcyclohexanone-2-carboxylate and olivetol followed by methylmagnesium iodide, a synthetic tetrahydrocannabinol was formed which had marihuana activity.

URBANA, ILLINOIS

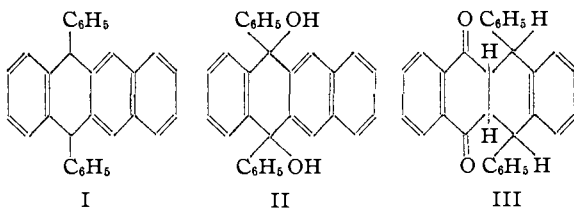
RECEIVED JULY 23, 1940

[COMMUNICATION FROM THE KODAK RESEARCH LABORATORIES]

## Action of Phenylmagnesium Bromide on Anthraquinones. II

BY C. F. H. ALLEN AND ALAN BELL

Some time ago, in a paper dealing with the synthesis of rubrene, Dufraisse and Horclois<sup>1</sup> treated naphthacenequinone with phenylmagnesium bromide in toluene, and obtained the diol II formed by 1,2-addition in a yield of 50%. They also obtained some of the 5,12-diphenylnaphthacene I, a very little of the 1,4-addition product III, and recovered a little quinone.



(1) Dufraisse and Horclois, *Bull. soc. chim.*, (5) **3**, 1894 (1936).

About the same time, Allen and Gilman<sup>2</sup> observed that when *n*-butyl ether was used as a solvent the same reagents gave none of the diol, but a considerable amount (20%) of the mixed stereoisomeric tetrahydro ketones III. Though not mentioned in that paper, the hydrocarbon I later was secured from the more soluble products in a yield of 25%. The discrepancy between the two papers led us to look into the reaction in more detail; it seemed *a priori* that the difference in results probably could be traced to differences in operating conditions. The results of this further investigation are described in this paper.

Before this particular instance was taken up, simple anthraquinones were used, to learn the optimum conditions for securing high yields of the

(2) Allen and Gilman, *THIS JOURNAL*, **58**, 937 (1936).

diols. In Table I are collected the results from a few substituted anthraquinones; the yields run from 70 to 90% if the butyl ether procedure<sup>3</sup> is followed. Several of these have been prepared

TABLE I  
YIELDS OF DIOLS; STANDARDIZED CONDITIONS, IN BUTYL

No.	ETHER Anthraquinone used	Yield, %
IV <sup>4</sup>	1-Chloro-	83
V <sup>5</sup>	2-Chloro-	90
VI <sup>6</sup>	2-Methyl- <sup>3</sup>	86
VII	2-Phenyl-	80
VIII	2,3-Dimethyl-	77
IX	2,3-Diphenyl-	80
X	1,2-Tetral-	70
XI <sup>7</sup>	1,2-Benz- <sup>8</sup>	78

previously in unstated yields. Diols have also been recorded for 1-phenyl-,<sup>9</sup> 1,4-dimethyl-,<sup>10</sup> 1,4-diphenyl-,<sup>9</sup> and 1,5-dichloro-<sup>4</sup> anthraquinones, but the operating conditions were not uniform. In no case has there been any evidence of 1,4-addition, as has been observed with certain polynuclear quinones.<sup>2,11</sup> After all the diol possible had been isolated, the residual untractable gum or resin was manipulated with a variety of solvents, but no solid was secured in any single instance.

A new complication was encountered with the linear four-ring systems; this was the production of the hydrocarbon corresponding to the expected diol. The relative amounts varied with the experimental procedure as described below. Thus, the action of the Grignard reagent on higher polynuclear quinones may give ketones resulting from 1,4-addition, diols resulting from 1,2-addition, and the hydrocarbons corresponding to the diols; the detection of a hydrocarbon indicates that 1,2 addition has occurred.

The hydrocarbon undoubtedly is formed by a process of reduction. It was found only in those runs in which the Grignard reagent was not *carefully filtered* from traces of magnesium metal; if the metal was completely removed, the expected diol was obtained, regardless of the nature of the solvent. This accounted for a part of the discrepancies between our results and those of Dufraisse; our glass wool filters used at the time

(3) Allen and McGibbon, *Can. J. Research*, **B16**, 35 (1938).

(4) Barnett, Cook and Wiltshire, *J. Chem. Soc.*, 1727 (1927).

(5) Ingold and Marshall, *ibid.*, 3087 (1926).

(6) Guyot and Staehling, *Bull. soc. chim.*, **33**, 1106 (1905), give a 95% yield.

(7) Clar, *Ber.*, **63**, 118 (1930).

(8) A similar run, using benzene as solvent, gave a 70% yield.

(9) Weizmann, Bergmann and Haselberg, *J. Chem. Soc.*, 391 (1939).

(10) Scholl and Meyer, *Ann.*, **512**, 112 (1934).

(11) Allen and Overbaugh, *THIS JOURNAL*, **57**, 740 (1935).

let through enough finely-divided magnesium to effect the reduction of the diol. If only traces pass through the glass wool, both diol and hydrocarbons are obtained. The results secured with a number of quinones are summarized in Table II.

TABLE II  
REACTION PRODUCTS OF C<sub>6</sub>H<sub>5</sub>MgBr AND POLYNUCLEAR QUINONES

Quinone used	Solvent	Diol	Yields, % Ke- Hydro- tone carbon
Naphthacene-5,12- <sup>a</sup>	Butyl ether	40	15
Naphthacene-5,12- <sup>a</sup>	Toluene	58	6
Naphthacene-5,12-	Butyl ether	0	20 25
Naphthacene-5,12- <sup>b</sup>	Butyl ether	27	15 12
6,11-Diphenylnaphthacene- <sup>a</sup>	Toluene	50 <sup>c</sup>	
6,11-Diphenylnaphthacene- <sup>a</sup>	Butyl ether	0 <sup>d</sup>	0
2,3-Tetral-	Butyl ether	0	66

<sup>a</sup> Reagent filtered from all magnesium. <sup>b</sup> Traces of magnesium metal present. <sup>c</sup> Checked reference 1. <sup>d</sup> Checked reference 2; *i. e.*, no reaction products isolated; 70% of starting material recovered.

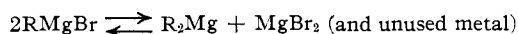
It is of especial interest to note that toluene is the preferred solvent with diphenylnaphthacenequinone; this accounts for the other discrepancy previously noted. Gilman and Jones<sup>12</sup> have recently pointed out the influence of solvents in reactions of organometallic compounds.

The question now arises as to how the hydrocarbon is formed from or instead of the diol. The Grignard reagent is known to have a reducing action,<sup>13,14</sup> but experiments showed that these linear diols were unaffected if the solution was free from traces of metal; if magnesium was present, these yielded 60–73% of the corresponding hydrocarbons. Table III shows the results of treating the diol II with the various reagents. The diol not

TABLE III  
EFFECT OF REAGENTS ON DIOL II

Reagent	Recovered diol, %	Diphenylnaphthacene, %
Mg + C <sub>6</sub> H <sub>5</sub> MgBr	0	65
C <sub>6</sub> H <sub>5</sub> MgBr	80	0
Mg	80	0
Mg + MgBr <sub>2</sub>	0	73

recoverable was accounted for by the production of a resin. The diols were unaffected by metallic magnesium alone, but reduced to the same hydrocarbons by the Gomberg-Bachmann reagent,<sup>15</sup> magnesium plus magnesium bromide. This combination is present in unfiltered Grignard reagent.



(12) Gilman and Jones, *ibid.*, **62**, 1243 (1940).

(13) Conant and Blatt, *ibid.*, **51**, 1227 (1929).

(14) Kharasch and Weinhouse, *J. Org. Chem.*, **1**, 209 (1937).

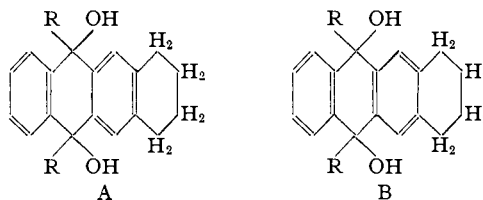
(15) Gomberg and Bachmann, *THIS JOURNAL*, **52**, 2455 (1930).

The reducing action, therefore, is not brought about by the  $\text{RMgBr}$  as such.

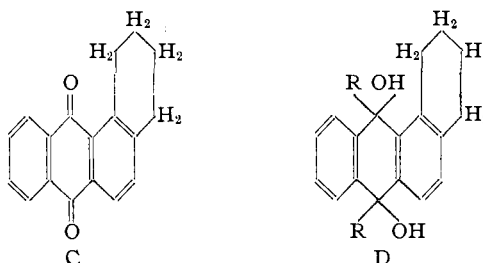
It might be argued that the hydrocarbon was formed from the diol by the action of heat alone, for it is well known that 9,10-diphenyl-9,10-dihydroxy-9,10-dihydroanthracene is "very unstable" and shows a great tendency to go over into 9,10-diphenylanthracene, by itself in organic solvents.<sup>16</sup> A careful examination of this particular instance was made because of the claim<sup>4</sup> that a "significant amount" of this hydrocarbon was secured on working up a xylene solution of one run (the yield of diol was but 50%, whereas it is 85–90% when one takes the precaution to get all the anthraquinone in solution).<sup>3</sup> It was found that in this case the formation of the hydrocarbon is a function of temperature during the treatment of the reaction product *after* it is formed. Appreciable amounts are secured only above 100°; for example, if the crude product is worked up by boiling with acetic acid, a 1% yield of hydrocarbon is secured. This accounts for the "significant amount" isolated when xylene was employed previously.<sup>4</sup> A similar situation obtained when the tetralanthraquinones were employed. However, neither the diol from anthraquinone nor 1,2-tetralanthraquinone was reduced by the metal combinations under the conditions which led to hydrocarbons from the linear four-ring quinones.

Since the diols obtained from all of the simple anthraquinones and angular benzanthraquinones examined so far are unaffected under the conditions just mentioned, this phenomenon appears to be associated with the presence of a linear fourth ring. Since it makes no difference whether the extra ring is reduced or not, its presence must have some effect on the tendency to removal of the OH groups. Also, as the diols obtained from 2,3-dimethyl- and 2,3-diphenylanthraquinones are unaffected by the reagents, it is not a case of simple  $\beta, \beta'$ -disubstitution, but a property of the ring as a whole. It seems probable that this effect is in some way connected with the bond arrangement of the intermediate ring.

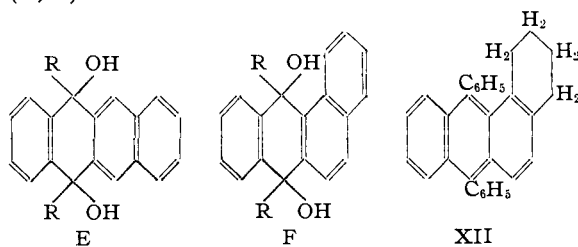
On comparison of the two structures (A, B) it will be noted that in B the bonds are located as in anthraquinone, none of the diols of which have exhibited the phenomenon of reduction. Hence, one would be inclined to prefer the arrangement shown in A. The fact that no instances of other



than 1,2-addition of the Grignard reagent to angular anthraquinones have been recorded would lead one to believe that these quinones, like the simple anthraquinones, have the bond structure shown in C. The observations that the diols in



the angular series are unreduced under the conditions which in the linear series yield hydrocarbons, encourage the idea that there has been no bond shift and that the arrangement shown in D is highly probable. If this line of reasoning is extended to the fourth unreduced ring, in each instance a normal naphthalene nucleus results (E, F).



Such a bond arrangement (E) has been shown to exist in naphthacenequinone.<sup>2,16a</sup>

Whatever the fine structures of the types that have been discussed, it is obvious that in the linear four-ring series the tendency is to form the hydrocarbon. This tendency seems to be absent in the simple anthraquinones and their angular derivatives.

### Experimental

**The Quinones.**—The requisite 2,3-dimethylanthraquinone was secured through a diene synthesis; it was not necessary to use a sealed tube as has been recommended for alkyl-substituted quinones in certain similar instances.<sup>17</sup> A mixture of 15.8 g. of  $\alpha$ -naphthoquinone, 9 g. of 2,3-di-

(16) Houben, "Das Anthracen und die Anthrachinone," Verlag Georg Thieme, Leipzig, 1929, p. 174.

(16a) Fieser, *THIS JOURNAL*, **57**, 1846 (1935).

(17) Fieser and Seligman, *ibid.*, **56**, 2690 (1934).

TABLE IV  
 PROPERTIES OF NEW 9,10-DIPHENYL-9,10-DIHYDROXY-9,10-DIHYDROANTHRACENES

No.	Other substituent	M. p., °C.	Crystal form	Formula	Analyses, %			
					Calcd.		Found	
					C	H	C	H
VII	2-C <sub>6</sub> H <sub>5</sub> <sup>a</sup>	203	Prisms	C <sub>32</sub> H <sub>24</sub> O <sub>2</sub>	87.2	5.5	87.1	5.5
VIII	2,3-Di-CH <sub>3</sub> -	227	Rods	C <sub>28</sub> H <sub>24</sub> O <sub>2</sub>	85.7	6.1	85.8	6.0
IX	2,3-Di-C <sub>6</sub> H <sub>5</sub> -	294	Needles	C <sub>38</sub> H <sub>28</sub> O <sub>2</sub>	88.4	5.5	88.6	5.5
X	1,2-Tetral-	226	Rods	C <sub>30</sub> H <sub>26</sub> O <sub>2</sub>	86.1	6.2	86.0	6.2

<sup>a</sup> Purified by chromatographic adsorption.

methylbutadiene, and 50 cc. of benzene was refluxed overnight. Most of the addition product crystallized on cooling and a further quantity was secured by concentrating the filtrate. The total yield was 19.9 g. (83%). It crystallizes from acetone or methanol in rods, m. p. 150°.

*Anal.* Calcd. for C<sub>16</sub>H<sub>16</sub>O<sub>2</sub>: C, 80.0; H, 6.7. Found: C, 79.7; H, 6.8.

When 14 g. was dissolved in 200 cc. of 5% alcoholic potassium hydroxide and air was bubbled through, the 2,3-dimethylantraquinone separated as yellow needles in a yield of 12.8 g. (96%). The melting point (209–210°) was unchanged by recrystallization from acetic acid.

**The Grignard Reaction.**—A standard procedure was adopted for the Grignard reaction in butyl ether as a solvent. As an example, the use of 2,3-dimethylantraquinone is given in detail; this gave the diol whether the reagent was filtered from traces of magnesium or not. The most suitable solvents for purification of the diols were benzene or dioxane.

**2,3-Dimethyl-9,10-diphenyl-9,10-dihydroxy-9,10-dihydroanthracene.**—The phenylmagnesium bromide was prepared in the usual manner from 79 g. of bromobenzene, 12.2 g. of magnesium turnings and 175 cc. of ether. Then 11.4 g. of 2,3-dimethylantraquinone in 150 cc. of dry butyl ether was added and the mixture heated with stirring for three hours (bath temperature of 100°), the ethyl ether being permitted to distill off. After cooling the reaction mixture was decomposed by iced acetic acid and steam-distilled to remove the solvent and biphenyl. The residue was triturated with 25 cc. of ether (in some instances a 1:1 mixture of ether–hexane was found preferable) and the crude diol filtered. It was extracted with alkaline hydro-sulfite to remove unused quinone (0.2 g.). The residual diol (m. p. 225–226°) was recrystallized from benzene (m. p. 225–226°) and finally from dioxane (m. p. 226–227°); the yield was 14.6 g. (77%). The gummy residue yielded no other products.

In a similar manner, 1-chloro-,<sup>18</sup> 2-chloro-,<sup>19</sup> 2-phenyl-,<sup>20</sup> 2-methyl-,<sup>19</sup> 2,3-diphenyl-,<sup>21</sup> 1,2-benz-,<sup>22</sup> and 1,2-tetral-<sup>23</sup> anthraquinones gave diols, the yields being recorded in Table II. Their other properties are recorded in Table IV.

Many of these polynuclear compounds did not separate as chemical individuals from mixtures, and required fractionation over alumina. The diols from the tetralanthraquinones are sensitive to heat, decomposing to yield the

corresponding hydrocarbons, so it is essential to avoid temperatures above 100°. The isolation of the pure diol from the reaction mixture, which is difficult, as has been noted by Dufraisse<sup>1</sup> in the case of the 2,3-isomer, is most readily accomplished by dissolving the crude diol in benzene and adding hexane to incipient crystallization.

With the compounds in the linear series, the same procedure was employed but the working up of the products was altered according to their nature. With naphthacenequinone in the absence of magnesium, unless particularly desired, the tetrahydro ketones III were not isolated, but were at once converted into 6,11-diphenyl-5,12-naphthacenequinone by aerating the alkaline mixture. For example, 8.6 g. of the mixture obtained from 10 g. of the quinone was suspended in 50 cc. of alcoholic potassium hydroxide solution and filtered from the diol. On aeration, the blue color disappeared and the yellow diphenylquinone precipitated. The diol II was recrystallized from benzene; its properties agreed with those given by Dufraisse.<sup>1</sup> When magnesium was present, the previously described manipulation<sup>2</sup> was employed. The ether solution from which the tetrahydro ketones III had been removed, was evaporated to dryness and manipulated with ether and petroleum ether repeatedly; eventually, 23% of the hydrocarbon I, 9,10-diphenylnaphthacene, was secured.

*Anal.* Calcd. for C<sub>30</sub>H<sub>20</sub>: C, 94.7; H, 5.3. Found: C, 94.3; H, 5.4.

Since larger quantities of the tetrahydro ketones were available, they were examined in more detail. The melting point of the higher stereoisomer was found to be 304°. Both were treated with methylmagnesium iodide in the Grignard machine; the results in Table V show they are ketones and not enols.<sup>24</sup>

TABLE V

Ketone	Active H <sub>2</sub>	Addition
High-melting	0.12	2.0
Low-melting	.15	2.0
(Benzoin, check)	1.06	0.95

With 2,3-tetralanthraquinone, and phenylmagnesium bromide containing magnesium, the residue after steam distillation was purified by acetone, then chloroform, and finally dioxane. Since the analytical figures for the resulting hydrocarbon were low, it was adsorbed on alumina from benzene solution, and elutriated with 60–90° petroleum ether. The diphenyltetrahydronaphthacene then gave the correct analysis.<sup>25</sup> In the absence of magnesium, the known diol A (R = C<sub>6</sub>H<sub>5</sub>) only was secured.

(24) Gilman, "Organic Chemistry, An Advanced Treatise," John Wiley and Sons, Inc., New York, 1939, p. 109.

(25) Dufraisse and Horelois, *Bull. soc. chim.*, (5), **3**, 1904 (1936), noted the difficulty of purification.

(18) Scott and Allen, "Organic Syntheses," Vol. 18, p. 15.

(19) This substance was furnished by the National Aniline and Chemical Company. Their assistance is gratefully acknowledged.

(20) Scholl and Neovins, *Ber.*, **44**, 1075 (1911).

(21) Allen, Bell and Eliot, *Can. J. Research*, **B17**, 86 (1939).

(22) Groggins and Newton, *Ind. Eng. Chem.*, **22**, 157 (1930).

(23) Schroeter, *Ber.*, **54**, 2242 (1921).

