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ACTION OF PHENYLMAGNESIUM BROMIDE
ON ANTHRAQUINONES.

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**ACTION OF PHENYLMAGNESIUM BROMIDE ON
ANTHRAQUINONES**

A Thesis

by

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**Presented to the Faculty of Graduate
Studies and Research in partial
fulfillment of the requirements for
the degree of Master of Science.**

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TABLE OF CONTENTS

Action of Phenylmagnesium bromide on Anthraquinones

	Page
Historical Introduction - - - - -	1
Table I - - - - -	2
Table II - - - - -	5
Table III - - - - -	11
Outline of Work and Discussion of Results - - - - -	13
Flow Sheet - - - - -	17
Experimental Introduction - - - - -	18
A Preparation of Phenylmagnesium bromide -	18
B Action of Phenylmagnesium bromide on	
Anthraquinone - - - - -	19
C Action of Phenylmagnesium bromide on	
β -methylantraquinone - - - - -	22
D Solvation of β -methyl- γ -diphenyl-	
anthraquinone diol - - - - -	25
E Derivatives - - - - -	27
Summary - - - - -	29

TABLE OF CONTENTS

The Fine-structure of Benzanthrone

	Page
Historical Introduction - - - - -	30
Outline of Work and Discussion of Results - - - - -	34
Flow Sheet - - - - -	37
Experimental Introduction - - - - -	38
A Methylation of Orthocresol - - - - -	38
B Friedel-Crafts Synthesis of 4'-methoxy- 5'-methylorthobenzoylbenzoic acid - - -	39
C Synthesis of 1-methyl-2-methoxy- anthraquinone and 1-methyl-2-hydroxy- anthraquinone - - - - -	41
D Preparation of 4'-methoxy-5'-methyl- orthobenzylbenzoic acid - - - - -	43
E Preparation of 1-methyl-2-methoxy- anthrone-9 - - - - -	44
F Preparation of 1-methyl-2-methoxy- anthrone-10 - - - - -	46
G Skraup Synthesis of 7-methoxy-8-methylbenzanthrone - - - - -	48
Summary - - - - -	49
Bibliography - - - - -	50

Historical Introduction

The action of the Grignard reagent on anthraquinones has been reported several times in the literature but the yields in the few instances where they are stated are generally very low (Table I). Improvements in the technique of Grignard reactions, the discovery in 1929 of 1,4-addition of the Grignard reagent, under "forced conditions", to an aromatic nucleus, and the increasing knowledge of polynuclear "fine-structure", that is, the position of the double-bonds in aromatic rings, have led to a renewed interest in the reaction between Grignard reagents and polynuclear substances. (53,86) The introduction is intended to review some of the methods and results of fine-structure determinations and to show the significance of ascertaining whether or not any 1,4-addition of Grignard reagents occurs in the anthraquinone series; a more complete list of the methods of determining fine-structure is given in the introduction of Part II.

The ozonolysis of o-xylene indicates that the triene in substituted benzenes is not fixed in one position. (72) Polynuclear compounds differ from benzenes in the dissimilar affinities possessed by centres of reaction in the same molecule, which are not the effect of activating groups. For example, Markwald and Fries have both noted the difference between the ortho-positions of β -naphthol and β -naphthylamine

Table I

Action of Grignard Reagents on Anthraquinones and on
Substituted Anthraquinones

Quinone	Grignard	Yield, Ref.	
		Diol %	
anthraquinone	phenylmagnesium bromide	10	(61)
"	"	50	(60)
"	"	80	(69)
"	"	34	(64)
"	"	50	(7)
"	"	50	(36)
"	methylmagnesium iodide	-	(58)
"	ethylmagnesium bromide	-	(26)
"	"	36	(27)
"	benzylmagnesium chloride	0	(62)
"	"	-	(83)
"	triphenylmethylmagnesium chloride	0	(64)
"	p-tolylmagnesium iodide	18	(64)
"	p-chlorophenylmagnesium iodide	-	(64)
"	p-bromophenylmagnesium iodide	-	(64)
"	p-anisylmagnesium bromide	-	(7)
"	"	-	(59)
"	"	38	(64)

Table I

Quinone	Grignard	Yield, Diol %	Ref.
anthraquinone	o-anisylmagnesium bromide	-	(59)
"	o-phenoxyphenylmagnesium iodide	47	(28)
"	o-xenylmagnesium iodide	25	(28)
"	α -naphthylmagnesium bromide	-	(57)
"	pyrrolmagnesium bromide	-	(78)
"	α -methylindolmagnesium bromide	-	(78)
α -chloranthraquinone	phenylmagnesium bromide	-	(7)
"	"	83	(10)
β -chloranthraquinone	"	-	(7)
"	"	-	(64)
"	"	90	(10)
β -bromanthraquinone	"	-	(64)
β -methylantraquinone	"	95	(57)
"	p-anisylmagnesium bromide	-	(59)
"	o-anisylmagnesium bromide	-	(59)
1,5-dichloranthraquinone	phenylmagnesium bromide	26	(7)
1,2-dimethoxyanthraquinone	ethylmagnesium iodide	18	(93)

and attribute the phenomenon to the fixed double-bonds of the symmetrical or Erlenmeyer fine-structure.(46) According to the Fries rule each ring of a polynuclear compound tends to assume the fine-structure of benzene.(48) Fieser and Lothrop have shown that the failure of certain substituted dinaphthols to couple supports the Erlenmeyer fine-structure for naphthalenes.(41) Tetralins, indanes, and benzenes with fused chelate rings react like benzenes, although the two latter ring systems show some indications of a fixed fine-structure, that is, of dissimilar ortho-positions which are not due to the directive influence of the substituents.(5,16,43,92) Polynuclear compounds may therefore be expected to have a fixed fine-structure in part or parts of the molecule due to the effect of fused unsaturated rings, while some compounds may have a single fine-structure for the entire molecule. A useful guide for predicting the probable fine-structure of polynuclears has been developed by Kehrman.(65) Many references to fine-structure are contained in a monograph on Polynuclear Hydrocarbons compiled by the Research Students in Organic Chemistry in 1936.

It has been shown by Fieser and Lothrop that the double-bonds in the two terminal rings of anthracene are fixed between adjacent α -positions and β -positions.(42) This agrees with the fine-structure deduced for anthracene by either the Fries rule or Kehrman's method (VIII, Table II), but does not determine the position of the triene of the central nucleus which can lead to two fine-structures (IX) for unsymmetrical anthracene derivatives. The weak basicity of β -anthramine and its failure to couple under the usual conditions are believed due to the predominance

Table II

Fine-structures and Double-bond Positions of
Polynuclear Compounds

VIII

X

IX

XI

XII

XIII

XIV

XV

Table II

XVI

or,

XVII

XVIII

XIX

XX

Table II H_2
XXI

O

XXII

XXIII

XXIV

XXV

XXVI

XXVII

of the fine-structure with the amine group in the non-benzenoid ring (X), which is the fine-structure which Kehrman's guide predicts for the compound. Pentacene derivatives (XI) might be expected to show similar anomalies. Anthracene, naphthacene, and pentacene, in order of increasing ease of reaction, react with maleic anhydride by 1,4-addition to the meso-positions.(68) The reactive meso-positions (9,10-,5,12-,and 6,13-, respectively) are those which would be expected from the fine-structures derived for the hydrocarbons by Kehrman's guide (VIII,XII,XIII), for in each case the reactive positions are the ends of the longer conjugated system; the increase in meso-activity may be accounted for by the increase in length of the conjugated system, which also explains the increase in depth of color of the hydrocarbons (colorless, orange, and blue, respectively).(70) Fieser and Martin arrived at the same fine-structure for naphthacene by means of the Fries rule.(44) The 1,2-benzanthracene, 1,2,5,6-dibenzanthracene, and 2,3,5,6-dibenzanthracene also add maleic anhydride to meso carbon atoms and in this case the relative meso-activity and the reactive positions (9,10-,1,4-, and 9,10-, respectively) also agree with the predicted fine-structures (XIV,XV,XVI).

In 1932 Clar reported the first cases of 1,4-addition of maleic anhydride to polynuclears without meso-positions.(22) The reaction differs from the usual diene synthesis involving meso-positions of anthracenes, naphthacenes, and pentacenes, in requiring a higher temperature and an oxidizing agent. Perylene and 2,3,10,11-dibenzperylene both add one mole of maleic

anhydride while 1,12-benzperylene and 1,12-benzperylene-Bz-1, Bz-2-dicarboxylic anhydride do not react. Also oxidation and halogenation of perylene yield 3,9-derivatives and 3,10-derivatives simultaneously. Clar wrote fine-structures for the four substances in which the perylene structure or residue is composed of two unsymmetrical naphthalene residues and has a plane of symmetry (XVII, XVIII, XIX, XX). Benzanthrone and phenanthrene will not add maleic anhydride in the presence of an oxidizing agent; the failure of phenanthrene to react agrees with the fine-structure determined by Fieser for the ring system by coupling and allyl rearrangements.(45)

Benzanthrone, on the other hand, in the absence of an oxidizing agent adds one mole of maleic anhydride so that it must have a fine-structure which contains a diene (XXI).(23)

A quinone, anthrone, or anil, cannot have the same fine-structure as the hydroquinone and other derivatives of the same polynuclear system so that separate determinations of fine-structure must be made; the isolation of a product of 1,4-addition of the Grignard reagent to the α,β -unsaturated carbonyl or anil serves to locate certain double-bonds in these compounds. The 1,2-addition and 1,4-addition of the Grignard reagent are competitive reactions whose rates depend upon the group in the Grignard reagent and the number, kind, and position of substituents in the ketone, so that the relative amounts of the products of 1,2-addition (an unsaturated alcohol) and 1,4-addition (a saturated ketone) are influenced by these factors; the medium and temperature have

little effect upon the mode of addition to aliphatic α,β -unsaturated ketones, but with aromatic ketones 1,4-addition sometimes occurs only when forced conditions are used.(67)

The 1,4-addition of the Grignard reagent to a benzene ring was first observed in 1929 by Gilman, while in 1932 Charrier and Ghigi reported the simultaneous 1,2-addition and 1,4-addition to a polynuclear ketone, benzanthrone, even in diethyl ether; in the case of 1,4-addition to benzanthrone the intermediate dihydrobenzanthrone was not isolated, probably on account of the tendency of dihydrobenzenes to become benzenoid.(18,53) Naphthacenequinone and excess phenylmagnesium bromide react by 1,2-addition to form the diol (2,3-benz-9,10-diphenyl-9,10-dihydroxy-9,10-dihydroanthracene) and by 1,4-addition to form two isomeric tetrahydrides (2,3-benz-1,4-diphenyl-1,4,4',9'-tetrahydroanthraquinones) which in alkaline solution are easily dehydrogenated by the air to 2,3-benz-1,4-diphenylanthraquinone; 2,3-benz-1,9-diphenylanthracene is also formed by reduction by the Grignard reagent (Table III).(2,34,35) The 1,4-addition of Grignard reagents to benzanthrone and naphthacenequinone supports the fine-structures (XXII,XXIV) predicted for the compounds by the Fries rule; the 1,4-addition also shows that both fine-structures contain a diquinonoid residue.(44) Since methylene anthrone was found to add active double-bonds to form XXIII benzanthrone it must also contain this residue.(24) The fine-structure predicted for 6,13-pentacenequinone (XXVII) by the Fries rule contains the analogous triquinonoid

Table III

Action of Grignard Reagents on Benzanthraquinones and
Tetralanthraquinones

Quinone	Grignard	Yields %			Ref.
		D*	H	K	
2,3-tetral-9,10- anthraquinone	phenylmagnesium bromide	60	**	0	(34)
1,2-benz-9,10- anthraquinone	"	***	0	0**	(21)
"	"	62	0	0	(10)
2,3-benz-9,10- anthraquinone	"	50	30	**	(34)
"	"	0	0	20	(2)
1,4-diphenyl-2,3- benz-9,10-anthraquinone	"	40	0	0	(37)
1,4-dihydroxy-2,3- benz-9,10-anthraquinone	"	40	***	0	(37)
1,4-diphenyl-2,3- benz-9,10-anthraquinone	"	0	0	0**	(2)
1,2,5,6-dibenz-9,10- anthraquinone	methylmagnesium bromide	88	0	0	(30)
"	n-butylmagnesium bromide	41	0	0	(30)
"	benzylmagnesium bromide	12	0	0	(30)

*-D: diol (1,2-addition),
H: hydrocarbon ("),
K: diketones (1,4-addition);

**-trace;
***-not stated;
**-starting material.
**

residue; Fries states that pentacenequinone is thus not a true para-quinone and in this way accounts for the observation of Clar and John that pentacenequinone does not form an aqueous alkaline vat (Liebermann reaction).²⁵(49) Naphthacenequinone and 6,11-diphenyl-5,12-naphthacenequinone do not form vats; however benzanthrone, which contains the diquinonoid residue (Introduction, Part II), and 1,2-benz-3,4-anthraquinone, which according to the Fries rule contains the diquinonoid residue, both form alkaline vats.(2,39,44) Fieser and Martin believe failure to form an alkaline vat accompanies a low reduction potential and results when a quinone and hydroquinone have fine-structures of similar stability. In contrast with the 1,2-addition and 1,4-addition of phenylmagnesium bromide to 5,12-naphthacenequinone, only 1,2-addition has been observed in the case of 6,11-diphenyl-5,12-naphthacenequinone, 6,11-dihydroxy-5,12-naphthacenequinone, and 2,3-tetra-9,10-anthraquinone; 1,2,5,6-dibenz-9,10-anthraquinone agrees with the fine-structure predicted for it by the Fries rule (XXV) in reacting only by 1,2-addition.(30,34,37) A simpler ring system, benzalanthrone-anil, reacts with the Grignard reagent by 1,4-addition although benzalanthrone and other anthrones which have been reported react only by 1,2-addition.(55) None of the polynuclear ortho-diketones are known to react with the Grignard reagent by 1,4-addition; 9,10-phenanthrene-quinone^{5,6-chrysenequinone} and acenaphthenequinone react by 1,2-addition only: (13,28,31,33,63,96,97) However the 1,2-anthraquinones and long quinone systems might be expected to react by

1,4-addition to an adjacent ring although no such instance has yet been reported; 2,3-dimethyl-1,4-naphthoquinone reacts by 1,4-addition but the group enters the quinone ring.(32) Koelsch and Rosenwald have found that phenyllithium will react by 1,4-addition to a polynuclear carbonyl and so may be used to locate a double-bond.(66)

Anthraquinone and several substituted anthraquinones have been found to yield diols with various Grignard reagents (Table I); an oxanthrone, the γ -disubstituted anthracene and the starting material (Flow Sheet) were often found in the product but no products of 1,4-addition have been reported. This has been used as evidence that the anthraquinone series has a fixed para-benzoquinonoid fine-structure (XXVI). It might be expected that under forced conditions 1,4-addition of the Grignard reagent to anthraquinones would occur; in order to determine whether this occurs it is necessary to carry out the reactions quantitatively and thus obtain a product free of oxanthrone and anthraquinone.

Outline of Work and Discussion of Results

Kovache has pointed out on the basis of his experiments that the use of a large excess (5 mols) of the Grignard reagent, finely divided (reprecipitated) anthraquinone, and stirring, are essential to good yields of diol.(69) This and other previous experiments were carried out before the modern improvements in the technique of the Grignard reaction

such as the "forced Grignard reaction" in which a large excess of an active Grignard reagent is employed, with toluene or some other high-boiling solvent as the medium. Normal-butyl ether was chosen in place of toluene in the following series of reactions since the ether is a better solvent. Six mols (3 equivalents) of Grignard reagent were used in order to ensure addition to both carbonyl groups and to avoid side-reactions such as reduction, which produces the γ -disubstituted anthracene.(29) Another precaution was to recrystallize the anthraquinones in such a way as to obtain them in a finely-divided form. When the above conditions were applied to a 5.0g. sample of anthraquinone a reproducible yield of 70-80% of the diol was obtained, so that the same procedure was adopted as standard.

No 1,4-addition product, which would be a quinone and colored, was found in the reaction with anthraquinone, nor was there any oxanthrone, although a few coarse particles (less than 0.1g.) were recovered; these were found to be anthraquinone and were shown to have an insoluble coating, even in the absence of water, possibly due to their having reacted only on the surface to form ROMgBr (Experimental, Section B). The particles of anthraquinone had evidently been entrained when the solution was decanted during the preliminary recrystallization. The acetone solution from which the diol was crystallized, when evaporated to dryness, left a gum which accounted for 15-20% of the product.

Four reactions were carried out; two were with

anthraquinone in n-butyl ether, and two with β -methylantraquinone, of which one was in diethyl ether, the other in n-butyl ether. There was no product of 1,4-addition in any of the reactions although in the case of β -methylantraquinone in n-butyl ether some of the residual gum was purified chemically by reduction (Experimental, Section E); this would reduce any diol which was present to the less soluble anthracene, and as was expected a precipitate of β -methyl- γ -diphenylanthracene was obtained. However the gum showed no halochromism, either of the diol or of the oxanthrone; this is unexpected since the above reduction seems to show that the gum contained diol, and in solution the gum did not give the characteristic fluorescence of β -methyl- γ -diphenylanthracene. Clarke and Carleton have reported that a reddish oil formed on the sides of the vessel when γ -diethylantraquinone diol was crystallized from the diethyl ether layer by evaporation; when no excess hydrochloric acid was used in decomposing the Grignard complex practically no oil was obtained. They showed that the reddish oil contained two non-fluorescent bimolecular products, one of which was fluorescent in solution, as well as anthraquinone; distillation in vacuo yielded γ -diethylantracene.(26,27) The reaction of β -methylantraquinone in n-butyl ether is the only one in which no starting material was found and it may be attributed to the greater solubility of β -methylantraquinone in n-butyl ether, since there was a residue of starting material when the reaction occurred in diethyl ether although the β -methyl-

anthraquinone used in both cases was recrystallized from the same solvent, acetic acid.

The yields of diol after one crystallization were 80% and 70% of the theoretical amount in the two reactions with anthraquinone; 86% with β -methylantraquinone in n-butyl ether, and in diethyl ether 66%. These yields are in agreement with those reported in the literature.(57,69). The yield of 86% of β -methyl- γ -diphenylantraquinone diol is made up of a 74% yield of diol obtained as such and a 12% yield based on the β -methyl- γ -diphenylanthracene which was recovered from the gum by potassium iodide and acetic acid reduction. The yield of diol from the reaction in diethyl ether is based on only the first crop of crystals from acetone so that a higher yield could probably be obtained.

More recent experiments by Bell* under substantially the same conditions, but employing 15.0g. samples, have shown that the α -chloranthraquinone and β -chloranthraquinone yield 83 and 90% of diol respectively with no indication of 1,4-addition products.(10)

The solvation which has been reported for the diols was also investigated.(69) The acetone solvate with β -methyl- γ -diphenylantraquinone diol was found to be stable enough at room temperature to determine the ratio of diol to solvent, which was found to be 1:2.

* The author wishes to thank Dr.C.F.H.Allen and A.Bell of the Eastman Kodak Company for permission to use these figures.

Flow Sheet

Experimental Introduction

The diols in acid solution are very reactive, being oxidizing agents ($2\text{KI} \rightarrow \text{I}_2$) and forming ethers and halides (VI). These reactions are made use of in the preparation of derivatives (Section E). (57,60) The diols precipitate from some solvents in the form of unstable solvated crystals.

The diols of both anthraquinones are white when pure and in concentrated sulphuric acid form indigo halochromic salts which turn to yellowish orange when heated; the oxanthrones form fuchsine halochromic salts. None of the products of the four runs gave fuchsine halochromic salts and some of the residual gums gave no halochromism.

The anthracenes (VII) fluoresce violet in most organic solvents.

A Preparation of Phenylmagnesium bromide

A 500cc three-necked flask containing 3.8g. (.156 mols) of magnesium turnings was fitted with a motor-driven stirring rod, a reflux condenser (with a bunsen valve), and a 100cc dropping funnel. The flask was swept free of air by illuminating gas entering by the funnel and passing out through the valve. Then 30cc (22.1g.; .30 mols) of dry diethyl ether was added to the flask through the dropping funnel; no air was permitted to enter the flask. The monobrombenzene, 18.4cc (27.4g.; .174 mols) dissolved in 30cc of diethyl ether, was placed in the dropping funnel and a few cubic centimetres of the solution were run into the flask. After the reaction had

been started by applying a small flame to the flask, stirring was started and the remainder of the brombenzene solution was run in just fast enough to keep the mixture refluxing. When the reaction had slowed down it was heated to refluxing on a steam-bath for about one hour.

B Action of Phenylmagnesium bromide on Anthraquinone

The dropping funnel was replaced by a wide-necked funnel and 5.0g. (.024 mols:.048 equivalents) of anthraquinone was quickly washed into the reaction flask by 80cc of redistilled n-butyl ether; the funnel was removed and replaced by a cork stopper. A water condenser was put in place of the reflux condenser and the free diethyl ether (about 10cc) was distilled off on an oil bath at $100^{\circ} \pm 5^{\circ} \text{C}$. The condenser was replaced by a stopper and heating was continued at 100° .

Some anthraquinone was still visible at the bottom of the flask when the stirring was stopped after heating for 1.5 hours; heating and stirring were continued for another 2.5 hours, after which the reaction solution was decanted from a small coarse residue which was washed by decantation with a few cubic centimetres of n-butyl ether. The residue weighed less than 0.1g. and was insoluble in boiling n-butyl ether, but when the yellow material was pulverised it was partially soluble and the filtrate deposited fine pale-yellow needles which were identified by mixed melting point as anthraquinone.

The decanted reaction solution gave a positive

Gilman test which indicates the presence of excess of the Grignard reagent. Then 100cc of 3.6% hydrochloric acid was added to the solution to decompose the addition product. The resulting mixture was steam-distilled until all of the ether and diphenyl were removed (about 1.5 litres of distillate); the corn-colored, granular, material in the distilling flask was filtered off, washed with water, and air-dried. The crude weight was 10.8g. (126% of the theoretical yield of unsolvated diol).

A one-third aliquot (3.6g.) of the crude product was dissolved by refluxing in methanol. An insoluble residue of 0.4g. of inorganic material (which did not melt at 300°, and left a large ash when burned), insoluble in water but soluble in acetic acid, was filtered off. This was probably basic magnesium salts and accounts for more than one-half of the 26% excess of the crude yield over the theoretical yield; the rest of the excess crude weight was probably due to solvation (Section C) or to inorganic material soluble in methanol.

By distilling off the methanol successive crops of white needle-shaped crystals were obtained which effloresced rapidly in the air, melted in the range 247°-252°corr. and weighed more than 2.3g. (80% of the theoretical yield) when air-dried. The melting points given in the literature for γ -diphenylanthraquinone diol are 247°uncorr., 252°-254°, and 260°-263°; for γ -phenyloxanthrone 207°uncorr. (7,60,64) The remaining acetone solution was evaporated to dryness and left

0.5g. of gum which was not investigated.

Anthraquinone recrystallized from chlorbenzene, and 100cc instead of 80cc of n-butyl ether were used in another reaction, which was heated for 5 hours and decomposed by 100cc of 3.6% hydrochloric acid. A yield of more than 6.1g. (70%) of unsolvated diol was obtained by recrystallizing the product from acetone and then from benzene. A small amount of anthraquinone, which was identified by mixed melting point, was recovered by recrystallizing the acetone residue from methanol. The benzene solution, on filtering, yielded less than 0.1g. of an inorganic residue, and when evaporated to dryness left a few particles of a reddish oil.

The melting-point of γ -diphenylanthraquinone diol recrystallized from methanol was found to be 259.5°-260.5°corr. The pure diol crystallized in the form of needle-shaped solvated crystals which effloresced rapidly to form a white powder.

The approximate volumes of various hot solvents required to dissolve 0.1g. of the diol, and the weight of diol recovered when cool, are: 2cc of acetic acid, 0.1g.; 2cc of ethyl acetate; 5cc of methanol, 0.1g.; 5.5cc of chloroform; 6cc of n-butyl ether; 10cc of acetone, 0.1g.; 14cc of i-propanol; >10cc of dioxane.

Similarly for anthraquinone: 1.4cc of chlorbenzene, 0.09g.; 10cc of acetic acid, 0.1g.; 30cc of n-butyl ether, 0.09g.; >10cc of n-butanol, 0.1g.; >35cc of acetone, 0.07g.

C Action of Phenylmagnesium bromide on β -methylantraquinone

The Grignard reagent was prepared as in Section A, the dropping funnel removed, and 5.0g. of β -methylantraquinone which had been recrystallized from glacial acetic acid was washed into the flask through a wide-necked funnel by 60cc of n-butyl ether. The funnel was replaced by a cork stopper and the reflux condenser replaced by a water condenser. The excess diethyl ether (about 10cc) was distilled off and the condenser replaced by a cork; the flask was then heated on the water-bath at about 100°.

After heating for about one-half hour all of the β -methylantraquinone had dissolved to form a green solution with a strong green fluorescence. The reaction was heated for 1.5 hours more after which the Gilman test was positive.

The addition product was decomposed by 150cc of 3.6% hydrochloric acid and the resulting mass was steam-distilled until no more diphenyl passed over (about 1.5 litres of distillate, including 60cc of n-butyl ether). The granular material in the distilling flask was filtered off, washed well with water, and pressed out. The light-brown colored crude product was air-dried overnight and then weighed 8.8g. (103%); it melted at about 224°corr. The melting-point given for the diol in the literature is 240°uncorr.(57) In sulphuric acid the crude material showed the intense indigo halochromism of the diol.

A 7.7g. portion of the product was refluxed in 60cc

of acetone and the solution was filtered while hot to remove scum. There was no residue on the filter paper so that the inorganic residue found at this stage in Section B is attributable to basic magnesium salts which were dissolved by the larger excess of hydrochloric acid used here in decomposing the complex.

Two crops of white microcrystals deposited by the acetone solution weighed 7.2g. after air-drying for a very short time. After 25 minutes in the Abderhalden drier at 111° the weight had decreased to 5.5g. (74%)(Section D); further drying did not alter the weight. The product was found to melt at 247°-248° corr. The melting-point given in the literature for β -methyl- γ -diphenylanthraquinone diol is 240° uncorr., for 2-methyl-9-phenyloxanthrone, the only oxanthrone which has been found in this reaction, 198°.(57)

A gum weighing 2.2g. was left behind when the residual acetone solution was evaporated to dryness. Small portions of the gum were macerated in concentrated sulphuric acid but showed no halochromism. However 0.5g. of the gum was reduced twice by potassium iodide in acetic acid (Section E) and yielded 0.2g. of material which gave no halochromism in sulphuric acid and melted over the range 186°-209°; a small amount precipitated from ethyl acetate by the addition of methanol melted over the range 206°-211° uncorr. and the mixed melting point with purified β -methyl- γ -diphenylanthracene (Section E) was 210°-215° uncorr. Since the gum was soluble in acetic acid, and the anthracene did not precipitate until

after the addition of the potassium iodide and boiling, the anthracene was not present in the gum; the failure of the gum to show the halochromism of the diol when macerated in sulphuric acid is unexpected. The 2.2g. of gum thus contained 0.9g. of diol.

The total yield of β -methyl- γ -^{diphenyl}anthraquinone diol was 6.4g. (86%). The melting-point of the white micro-crystals of pure, unsolvated, diol was found to be 247°-248° corr.

A second experiment was carried out in which 80cc of refluxing diethyl ether was used instead of n-butyl ether, and in this case about 0.1g. of unreacted, granular, β -methyl-anthraquinone (which was identified by mixed melting point) was recovered when the solution of the undecomposed addition product was decanted from the residue in the reaction flask (Section B). Although the addition product was decomposed by 100cc of 7.2%, instead of 3.6%, hydrochloric acid, in order to dissolve basic magnesium salts, the crude product weighed 8.7g. (103%); however the yield was reduced to 8.4g. (100%) by placing the product in the Abderhalden drier at 110° for 45 minutes and the weight did not alter on further drying at 110° for 30 minutes. The dry crude yield of not more than 100% in this case is probably due to the use of sufficiently strong acid to dissolve basic magnesium salts (Section B). The 8.4g. of material was dissolved in acetone and left a residue of less than 0.1g. of inorganic material and yielded a precipitate of more than 7.3g. of solvated diol; the diol was dried in

the Abderhalden drier to 5.6g. (66%). The residual gum was not purified chemically.

The approximate volumes of various hot solvents required to dissolve 0.1g. of the β -methyl- γ -diphenylanthraquinone diol are: 1.2cc of acetone, 2cc of acetic acid, 2cc of pyridine, 4.5cc of methanol.

D Solvation of β -methyl- γ -diphenylanthraquinone diol

A sample of 1.0g. of the unsolvated diol from Section C was placed in a test-tube and dissolved in the minimum (12cc) of boiling acetone; the solution was cooled and the precipitate of solvated diol was filtered off. The 0.9g. of precipitate was spread in a thin layer and air-dried for several minutes.

A 0.50g. sample of the solvated diol was placed in a dry sample bottle which was set in the bottom of a large test-tube closed by a two-holed rubber stopper; a long glass tube fitted at the upper end with a small piece of rubber tubing and a screw-clamp was passed through the stopper so that its lower end was immediately above the level of the diol. A 250cc erlenmeyer flask, which contained 100cc (a 65% excess) of a 0.5% ethanol solution of 2,4-dinitrophenylhydrazine (which had been dissolved by refluxing), was closed by a two-holed rubber stopper fitted with a short bent tube which was connected to the bunsen vacuum pump. Through the other hole was passed a glass tube which went beneath the surface of the ethanol solution and almost to the bottom of

the flask. The upper end of this tube, bent through an angle of about 150° , was passed almost through the second hole in the stopper of the large test-tube. This arrangement permitted vapor evolved from the diol to be swept by air-pressure into the ethanol solution where a derivative of acetone would form if any acetone were present in the vapor.

The apparatus was tested for air-tightness, and 15cc of concentrated hydrochloric acid was added to the hot ethanol solution. A beaker partially full of water, and containing a thermometer, was placed so that the water almost touched the bottom of the large test-tube which contained the diol. The screw-clamp was closed tightly and the beaker was heated slowly by a small flame. Bubbles started to pass through the ethanol solution when the temperature of the water was about 30° although at first they were probably due to expansion of air in the test-tube. The temperature of the bath was raised during 5 minutes to about 87° , and maintained there until bubbles had practically ceased forming (10 minutes). Suction was turned on and the screw-clamp was opened to permit a slow stream of air to sweep the vapor into the ethanol solution. After about 10 minutes crystals had ceased forming in the ethanol solution so after a further 10 minutes suction the apparatus was opened.

The loss in weight of the diol was 0.11g. ($22 \pm 4\%$). The theoretical percentage losses in weight for solvation by 1, 2, and 3 mols of acetone are 13.3, 23.5, and 31.5 respectively, so that the solvation is in the ratio of 1 mol of

diol to 2 mols of acetone.

The ethanol solution in the erlenmeyer flask was boiled for 4 minutes, diluted with water (120cc) and allowed to cool. Orange microcrystals deposited and were filtered off and dried. They weighed 0.36g. (75%) and melted at 123.5°-124.5° uncorr.; the mixed melting point with pure 2,4-dinitrophenylhydrazone of acetone was 124°-125° uncorr.

E Derivatives (57,60)

γ-dichlor-γ-diphenyl-γ-dihydroanthracene

0.5g. of unsolvated γ-diphenylanthraquinone diol was dissolved in 10cc of boiling glacial acetic acid and 1cc of concentrated hydrochloric acid was run in by pipette. The solution containing the heavy white precipitate of the dichloride which formed was heated to boiling, allowed to cool and filtered; the residue was washed well with the filtrate and with a small amount of glacial acetic acid. The yield was about 0.5g. (80%). The material turned yellow (due to the formation of the anthracene) at 156° and flowed at 175° corr. The literature states that the compound melts with decomposition at about 178°. The filtrate was a faint violet color with a violet fluorescence, probably due to the presence of the anthracene.

γ-diphenylanthracene

0.5g. of unsolvated γ-diphenylanthraquinone diol was dissolved in 10cc of glacial acetic acid by boiling, a small drop of mercury was added, and 1cc of aqueous potassium

iodide (which contained 1g./cc) was run in by pipette. The solution became red due to the liberation of free iodine and then a voluminous precipitate of small yellow needle-shaped crystals formed. The mixture was shaken, heated to boiling, and the precipitate filtered off; the color of iodine was removed by washing with glacial acetic acid. A yield of more than 0.3g. (60%) was obtained. The γ -diphenylanthracene melted at 251°corr. and did not sublime at 295°. The literature states that the anthracene is in the form of amber crystals which melt at 240°uncorr., 249°-250°, and sublime without decomposition at about 270°.(60,64)

β -methyl- γ -diphenylanthracene

This was prepared in the same manner as γ -diphenylanthracene from unsolvated β -methyl- γ -diphenylanthraquinone diol. The precipitate formed more slowly than above. A yield of 0.4g. (80%) was obtained of light yellow microcrystals which melted at 220°-222°corr. A small sample was recrystallized from ethyl acetate and it flowed at 218° and became clear at 222°corr. The literature states that the anthracene is in the form of green-yellow crystals which melt at 213°. Acetic acid, acetone, and ethyl acetate solutions of the anthracene have a violet fluorescence.

Summary

- 1 The reaction of phenylmagnesium bromide and anthraquinone under "forced conditions" yields 70-80% of γ -diphenylanthraquinone diol when the complex is decomposed by hydrochloric acid.
- 2 β -methylantraquinone under similar conditions yields 86% of the diol. In diethyl ether the yield of diol is 66%.
- 3 A product of 1,4-addition was not detected although 15-20% of the product in each case was a gum which would not crystallize.
- 4 Traces of the anthraquinone, when found, were in the form of granules which had an insoluble coating, probably of ROMgBr , which had prevented them from dissolving. There was no indication of an oxanthrone in any of the reactions.
- 5 β -methyl- γ -diphenylanthraquinone diol precipitates from acetone solution with 2 molecules of acetone of solvation.

Historical Introduction

The position of the double-bonds in the benz-nucleus of 1,9-benzanthrone (Flow Sheet, I, Bz) is reasonably certain on the basis of oxidation reactions which were known before 1930, while as early as 1911 Bally and Scholl had placed these two double-bonds in the positions shown.(89) When oxidized by means of chromic acid, benzanthrone and its Bz-derivatives produce anthraquinone-1-carboxylic acid; Bz-1-carboxy-2-methoxybenzanthrone methyl ester and Bz-1-arylbenzanthrones yield as intermediate cleavage products α -(2-methoxyanthraquinonyl-1)-glyoxalic acid methyl ester and 1-aryl anthraquinones respectively. Chromic acid also oxidizes 4-methylbenzanthrone, 4-butylbenzanthrone, and 4-benzylbenzanthrone to 4-substituted anthraquinone-1-carboxylic acids, although 4-phenylbenzanthrone yields the lactone of 1,2,3,4-dibenz-xanthone-1'-carboxylic acid.(3,15,18,19) Permanganate oxidizes 4-phenylbenzanthrone to 4-phenylanthraquinone-1-carboxylic acid.(3) Manganese dioxide in sulphuric acid causes bimolecular oxidation.(75) The above cases in which oxidation cleaves the Bz-nucleus show that the double-bonds in the Bz-nucleus are between atoms 9 and Bz-3, and between Bz-1 and Bz-2; however it must be assumed that the oxidizing agent does not change the position of the double-bonds, either by direct action or induction. Although benzanthrone does not add maleic anhydride, benzanthrene does, and this might be used to support the fine-structure determined by the oxidation

of benzanthrones; however the effect of the carbonyl upon the fine-structure is not known (Introduction, Part I).(23)

Charrier and Ghigi, and Allen and Overbaugh, have reported that benzanthrone produces a 1,4-addition product when treated with some Grignard reagents although the yields of 4-substituted benzanthrones are not high, probably on account of simultaneous oxidation and reduction of the intermediate dihydro addition product, which was not isolated, or the simultaneous formation of carbinols by 1,2-addition. The 1,4-addition requires the presence of a double-bond between atoms 4 and 4'; the other two conjugated double-bonds must be between carbon atoms 2 and 3, and between atoms 1 and 9', so that the Bz-nucleus and the adjacent non-carbonyl nucleus constitute together an Erlenmeyer naphthalene fine-structure as predicted by the Fries rule. This would account for the reactive positions, 2 and Bz-1, of benzanthrone in substitution reactions such as bromination, nitration, mercuration, and condensation, for they are the α -positions of the naphthalene residue.(12,71,74,85)

The triene in the non-carbonyl nucleus may or may not be fixed; the purpose of the investigation was to determine the fine-structure of this nucleus and so complete a determination of the fine-structure of benzanthrone. Some of the methods employed in the determination of fine-structure are mentioned in the following paragraph.

The properties of unsaturation and activation are the basis of reactions which have been used to locate isolated

and conjugated double-bonds, both aliphatic and aromatic.(52) The characteristic reactions of simple addition to the double-bond, such as nitration and bromination, serve both to detect and to locate isolated double-bonds but generally indicate only the ends of conjugated systems (or yield mixtures of products of 1,2-addition and 1,4-addition), while in ring conjugated systems such as occur in the aromatic series they must be applied to substituted compounds. The phenol or amine is most often used since the substituent must activate the ortho-positions and supply a hydrogen atom for the elimination reaction when the double-bonds are fixed and a substituted ketone results.(47) Further characteristic reactions of the isolated double-bond which involve addition are oxidation, the Claisen rearrangement of allyl ethers, the coupling of diazoic acids, and ozonolysis.(20) Oxidation is generally a severe reaction and may cause double-bonds to shift although when different oxidising agents yield the same products, as in the case of benzanthrone, the likelihood is diminished. The mechanism of coupling is believed to require addition to a double-bond.(51) The Claisen rearrangement and coupling must be applied to suitably substituted compounds and two different derivatives are required for each determination.(41) Ozonolysis involves bridge formation before cleavage so that it may be used with unsubstituted molecules including the hydrocarbon.(72) The diene synthesis (which is a reaction between a conjugated pair and an active double-bond), and the Grignard reaction, may be used to locate

a few aromatic double-bonds.(1) A carbonyl must be in the α -position to the double-bond in order to use the Grignard reagent, which may add to the 1,4-position, a reaction first noted with aromatic double-bonds in 1929 (Introduction, Part I). (53) Koelsch and Rosenwald have shown that phenyllithium and 8-phenyl-peri-naphthindanedione-7,9 yield 1,8-diphenyl-1,9- α -dihydro-peri-naphthindanedione-7,9; this locates a double-bond in the former compound by indicating the position of the α,β -unsaturation.(66) The activating effect of the carbon-nitrogen double-bond upon the methyl group in condensation with benzaldehyde has been employed by Mills and Smith to prove that isoquinolines have a symmetrical or Erlenmeyer naphthoid fine-structure.(77) The Skraup synthesis has been used to determine fine-structure but since it changes the ring system it may indicate a fixed fine-structure to be labile as in the case of 1-chlor-2-naphthylamine.(50) The fusion of some 5 and 6-atom unsaturated rings is known to fix the position of the double-bonds of labile fine-structures (Part I), and as has just been mentioned it may alter a fixed fine-structure for it changes the conjugation.(5)

The most useful methods for determining fine-structure are the coupling of diazoic acids, the rearrangement of allyl ethers and the 1,4-addition of Grignard reagents. Allen and Overbaugh found that the 4-substituted benzanthrone mentioned above add one mole of several Grignard reagents but no products could be isolated so it was not determined whether a carbinol had formed or whether 1,4-addition to the 5-position

had occurred; the latter would have proven that the fine-structure is capable of existing as in II.(3) The diazoic acid and allyl ether methods both require an enol with one ortho position occupied by a group such as methyl which is difficult to remove. Substituted benzanthrone which might be used in these methods to determine the fine-structure of the ortho-fused nucleus of benzanthrone are: 7-hydroxy-8-methylbenzanthrone, 5-methyl-6-hydroxybenzanthrone, 6-methyl-7-hydroxybenzanthrone, and 6-hydroxy-7-methylbenzanthrone, none of which are known substances. The first-mentioned compound, 7-hydroxy-8-methylbenzanthrone (XIV), was chosen since it seemed most accessible.

Outline of Work and Discussion of Results

The benzanthrone ring system has been synthesized by the addition of the benz-nucleus to an anthraquinone, anthrone, oxanthrone, or methyleneanthrone; by closing the carbonyl ring through either of the carbonyl bonds or through the carbon-carbon peri-bond; by the addition of a nucleus to phenanthrenequinone; and by the degradation of perylene.^(6,24, 76,87,88,90,91,95)⁹⁸ The Skraup synthesis of the benz-nucleus by means of acrolein and an anthrone was chosen because the required anthrone, 1-methyl-2-methoxyanthrone-10 (XII), is readily accessible from the anthraquinone (IX) which is a known substance; because the synthesis would be expected to form only one product (XV) free of isomers; and because

methyl groups do not shift in the Skraup synthesis as they are known to in some cases of the peri-closure method which uses aluminium chloride.(11,38)

The literature gives no proof of structure for 1-methyl-2-hydroxyanthraquinone (VIII) and 1-methyl-2-methoxyanthraquinone (IX) beyond their syntheses, so in view of Fieser's observation on the difficulty of ring closure meta to a methoxyl group, and the para-closure of an orthobenzylbenzoic acid which was reported by Bistrzycki and Zen-Ruffinen, it was decided to try to couple 1-methyl-2-hydroxyanthraquinone (VIII) with benzene diazonium chloride.(14,40,80) If coupling had occurred it would have indicated that ring-closure of 4'-methoxy-5'-methylorthobenzoylbenzoic acid (VII) had taken place para to the methyl group, instead of ortho as expected; however, failure to couple, by itself, is not a proof of structure. The structure of 7-hydroxy-8-methylbenzanthrone (XIV) might be proven by methylation to XV, in order to stabilize XVI and XVII, and chromic acid oxidation of XV to XVI or XVII. Both XVI and XVII may be synthesized by the Friedel-Crafts synthesis from orthocresol methyl ether (V) and hemimellitic acid (XXI).(56)

The synthesis of the benzanthrone (XIV) was carried as far as the two isomeric anthrones: 1-methyl-2-methoxyanthrone-9 (X) and 1-methyl-2-methoxyanthrone-10 (XII). The Skraup synthesis of XV from XII and acrolein could not be effected even by the procedure of Allen and Overbaugh; cinnamic aldehyde did not react under the various conditions

which were tried.(4)

Three compounds which are not mentioned in the literature have been prepared and analyzed for carbon and hydrogen: 4'-methoxy-5'-methylorthobenzylbenzoic acid (VII), 1-methyl-2-methoxyanthrone-9 (X), and 1-methyl-2-methoxyanthrone-10 (XII).

Flow Sheet

I

II

III

XIX

IV

V

VI

VII

XX

VIII

IX

X

XXI

XI

XII

XVI

XXII

XIV

XV

XVII

XVIII

The bracketed compounds were not prepared.

Experimental Introduction

Ortho-cresol was methylated by means of dimethyl sulphate.(79) Orthocresol methyl ether (V) and phthalic anhydride take part in a Friedel-Crafts condensation in carbon bisulphide and form 4'-methoxy-5'-methylorthobenzoylbenzoic acid (VI); this was converted into 1-methyl-2-methoxyanthraquinone (IX), and 1-methyl-2-hydroxyanthraquinone (VIII), by ring closure and partial demethylation with sulphuric acid.(11) The anthrone (X) which is obtained by alkaline reduction of 4'-methoxy-5'-methylorthobenzoylbenzoic acid (VI) and sulphuric acid ring closure of the resulting 4'-methoxy-5'-methylorthobenzoylbenzoic acid (VII) is different from XII, which forms when 1-methyl-2-methoxyanthraquinone (IX) is reduced by the Liebermann method.(8,9,73,94) Thus XII must be 1-methyl-2-methoxyanthrone-10, the anthrone which is desired for the Skraup synthesis of XV.

A Methylation of Ortho-cresol (IV)(79)

A 3-l. three-necked flask containing 270g. (2.5 mols) of *ortho-cresol* (IV) and 100 g. (2.5 mols) of sodium hydroxide dissolved in 200cc of water, and 800cc of wash water, was cooled to 10° by an ice and salt bath. It was then fitted with a reflux condenser, a motor-driven stirring rod, and a dropping funnel containing 315g. (235cc: 2.5 mols) of dimethyl sulphate, which was run in with stirring during 40 minutes. After removing the bath, the flask and contents were heated on a boiling water-bath for 35 minutes,

then allowed to cool. The ether layer (V) was separated from the aqueous in a separatory funnel and dried over calcium chloride for one week. The crude yield was 88%. The crude ether (V) was then decanted and distilled with porcelain chips from a 1-l. distilling flask. The yield of distilled ether (V) was 218cc (70%) with a boiling point in the range 168°-174°.

There was some loss owing to a fire during distillation. The ether (V) may be washed with water in order to remove sodium hydroxide before drying over calcium chloride.

B Friedel-Crafts Synthesis of 4'-methoxy-5'-methyl-orthobenzoylbenzoic acid (VI)(11)

A 3-l. three-necked flask containing 240g. (1.6 mols) of phthalic anhydride, 200g. (205cc: 1.6 mols) of orthocresol methyl ether (V), and 650cc of carbon bisulphide was fitted with a reflux condenser and a motor-driven stirring rod. A bottle containing 240g. (1.8 mols) of aluminium chloride was attached and the aluminium chloride was added with stirring during about one hour. The red reaction mass was heated for about four hours on the steam-bath, then let stand for 18 hours. The complex was decomposed by 1-l. of ice and water which contained 150cc of concentrated hydrochloric acid. The mixture was heated on the steam-bath and steam-distilled whereby 675cc of water-insoluble liquid was recovered from 1,600cc of distillate. The sludge which remained in the distilling flask was cooled and filtered on a 20cm Buechner

funnel. The moist filter cake was dissolved by heating it in 3-l. of water which contained 185g. (3.5 equivalents) of anhydrous sodium carbonate (required to neutralize the 150cc of concentrated hydrochloric acid and the 440g.: 1.6 mols of 4'-methoxy-5'-methylorthobenzoylbenzoic acid (VI)); the precipitate of aluminium hydroxide (12g.) was filtered off from the hot solution. The filtrate was treated with 200cc of concentrated hydrochloric acid which precipitated the organic acid (VI); this was filtered off, pressed out, and air-dried. The dry yield of VI was 207g. (47.5%); it melted over the range 187.5°-190° uncorr.

A further 150cc of concentrated hydrochloric acid was added to the filtrate and precipitated 97g. of phthalic acid. The 675cc of water-insoluble steam-distilled liquid was dried by calcium chloride and fractionally distilled; 525cc of carbon bisulphide were recovered together with 75cc of orthocresol methyl ether (V). The product and recovered starting materials thus account for 84% of the reactants.

This experiment followed the literature in the use of 1.1 mols of aluminium chloride for each mole of phthalic anhydride. It is now customary to employ 2.2 mols of aluminium chloride for each mol of an acid anhydride in Friedel-Crafts reactions, and this, or phthalide formation, may account for the low yield of 47.5%. (17,84) Also carbon bisulphide is an unsatisfactory medium since the Perrier compound is insoluble and too stiff to stir properly; tetrachlorethane or nitrobenzene might be preferable media in

this respect. A reaction was carried out with one-tenth the quantities of reactants, including the solvent, which were employed above; stirring could be kept up for about one hour and, with heating for 11 hours, a yield of 29.3g. (67%) of VI was obtained.

The organic acid VI, when recrystallized from ethanol and chloroform to a constant melting point, is a white microcrystalline substance which melts at 191° - 192° uncorr. The melting-point given in the literature is 176° .

C Synthesis of 1-methyl-2-methoxyanthraquinone (IX) and
1-methyl-2-hydroxyanthraquinone VIII by
Sulphuric acid Dehydration (11)

A 250cc extraction flask containing 80cc of concentrated sulphuric acid and fitted with a drying tube was preheated at $142^{\circ} \pm 2^{\circ}$ on an oil-bath; 16.0g. of 4'-methoxy-5'-methylorthobenzoylbenzoic acid (VI) was added and the red halochromic solution was kept at 142° for 10 minutes with occasional shaking. The hot solution was very slowly poured down the inside of a beaker which contained 1,600cc of boiling water. The precipitation required 20 minutes owing to the severe spattering which occurred; goggles and towels were necessary. The resulting precipitate filtered rapidly, which is not the case when the vat is cooled before being precipitated. The green cake was washed on the Buechner filter with warm water, then stirred into 140cc of a 2% sodium hydroxide solution and boiled for 15 minutes in order to

dissolve 1-methyl-2-hydroxyanthraquinone (VIII). The alkaline mixture was filtered and the residue washed with hot 2% sodium hydroxide solution and hot water. The yield of the air-dried green 1-methyl-2-methoxyanthraquinone (IX) was 8.9g. (61%). The filtrate was treated with an excess of hydrochloric acid and the green precipitate of 1-methyl-2-hydroxyanthraquinone (VIII) was filtered off and air-dried. The yield of VIII was 2.7g. (18%); the combined yield of IX and VIII was 11.6g. (79%).

Demethylation may be decreased by lowering the temperature of the reaction, by shortening the reaction time, and by decreasing the ratio of sulphuric acid to organic acid (VI); the yields at 155° are similar to those at 140°, while at 120° ring closure takes place slowly. Prolonged heating and a concentrated reaction solution lower the combined yield by causing charring. The dilution time was reduced to less than one minute (since there was no spattering, and only a slight foaming), and there was no demethylation when 3cc of sulphuric acid per gram of organic acid (VI) (instead of 5:1 as above) were used, the reaction mixture heated for 7 minutes and poured into 3 times its volume of boiling 20% sulphuric acid (110°), which was in turn poured into twice its volume of boiling water. In this case 30-50% of the organic acid (VI) was recovered unchanged so that the yield of methylated anthraquinone (IX), calculated on the basis of unrecovered starting material, was raised to 75-80%. Much larger quantities are employed when dilution is carried out

in two stages since it is less tiresome.

The 1-methyl-2-methoxyanthraquinone (IX), when it is recrystallized to a constant melting-point from methanol and chloroform, forms pale yellow thread-like crystals which melt at 198° uncorr. and form a non-fluorescent, cherry colored, halochromic solution in sulphuric acid, which when diluted with water leaves a pale yellow turbidity. The melting-point given for IX in the literature is 184° .

The 1-methyl-2-hydroxyanthraquinone (VIII), recrystallized from 5% sodium hydroxide solution and ethanol to a constant melting-point, forms canary yellow powders which melt at 300° uncorr. and in concentrated sulphuric acid form a reddish-orange halochromic solution which is non-fluorescent; the halochromic solution, when diluted with water, forms a pale turbidity of a yellow color. The melting-point given in the literature is $> 300^{\circ}$.

The 1-methyl-2-hydroxyanthraquinone (VIII) would not couple with benzene diazonium chloride; this supports the proof of the structures of VIII and IX which is supplied by their synthesis. (80)

D Preparation of 4'-methoxy-5'-methylorthobenzoylbenzoic acid (VII) by Alkaline Reduction (8,9,94)

A 50cc extraction flask, containing 1.0g. of 4'-methoxy-5'-methylorthobenzoylbenzoic acid (VI), 2.0g. of zinc dust, 12cc of concentrated aqueous ammonia, 4cc of water and 0.2g. of copper sulphate crystals (catalyst), was fitted

with a one-holed rubber stopper which contained a short reflux tube. The reaction mixture was boiled gently (in order to retain the ammonia) for 10.5 hours, filtered while hot by decantation, and washed with a few cubic centimetres of aqueous ammonia. The residue was dissolved by boiling in 30cc of water which contained 0.5g. of sodium carbonate and the solution filtered off. Acidification of the two filtrates by an excess of hydrochloric acid produced, when it had been filtered off, washed, and dried, 0.8g. (80%) of a white powder which melted at $152^{\circ}\text{uncorr.}$

The 4'-methoxy-5'-methylorthobenzylbenzoic acid (VII) has not been reported in the literature; when recrystallized to a constant melting-point, from chloroform with charcoal and methanol, it forms white microcrystals which melt at $152.5^{\circ}\text{uncorr.}$

	C	H
Calculated,		
for $\text{C}_{16}\text{H}_{16}\text{O}_3$, %	74.9	6.29
Found, %	74.84	6.29

E Preparation of 1-methyl-2-methoxyanthrone-9 (X) by
Sulphuric acid Dehydration (94)

A 1.9g. sample of powdered 4'-methoxy-5'-methyl-orthobenzylbenzoic acid (VII) was added to 20cc of concentrated sulphuric acid at 24° (room temperature). The orange colored solution was shaken occasionally during 15 minutes

and was then poured on to about 100g. of cracked ice. The resulting mixture was diluted to 200cc, filtered, and washed with water. The dry crude residue was almost white in color, weighed 1.7g. (90%), and melted at 124° - 127° uncorr; it was recrystallized with charcoal from 50cc of boiling methanol and produced 0.9g. (45%) of light tan colored 1-methyl-2-methoxyanthrone-9 (X) which melted at 136° - 136.5° uncorr. A further 0.3g. of impure anthrone (X), which melted at 127° uncorr., precipitated when the methanol solution cooled. The melting point of the anthrone (X) was raised to 137° uncorr. by recrystallizing it from carbon bisulphide.

The 1-methyl-2-methoxyanthrone-9 (X) has not been reported in the literature; in sulphuric acid it forms a pale greenish yellow halochromic solution which leaves a white turbidity when diluted with water.

Calculated,	C	H
for $C_{16}H_{14}O_2$, %	80.6	5.93
Found, %	80.48	5.90

The methanol residues (0.9g.) from this and other runs were boiled in a dilute solution of sodium hydroxide for one-half hour in order to remove any alkali-soluble material (e.g: VII), and the residue, which weighed 0.8g. and melted over the range 127° - 138° uncorr., was dissolved in 30cc of methanol by boiling for one hour. The hot methanol solution was filtered and left 0.05g. of a glistening, white, micro-crystalline organic residue which melted at 210° uncorr.; the

melting-point was raised to 212° uncorr. by recrystallizing from methanol. The substance was not characterized but may be an isomer of X, such as 2-methyl-3-methoxyanthrone-9, formed by para ring closure (Introduction). The sulphuric acid halochromic solution of this substance is green with no visible fluorescence and upon dilution with water a clear solution is left.

F Preparation of 1-methyl-2-methoxyanthrone-10 (XII) by
Liebermann Reduction (73)

A 1-l. flask fitted with a reflux condenser and containing 10.0g. of crude 1-methyl-2-methoxyanthraquinone (IX) and 500cc of glacial acetic acid was heated to boiling in order to dissolve the anthraquinone (IX), which formed an opaque green solution. Refluxing was discontinued while 25g. of mossy (or granular) tin was introduced to the flask and 10cc of concentrated hydrochloric acid were run in (slowly in order to prevent foaming) by pipette. After 5 minutes refluxing another 10cc of hydrochloric acid was added, and the addition was repeated twice more, when a total of 40cc had been added. The reaction mixture was refluxed for 5 minutes after the last addition (a total reaction time of 20 minutes), and a small sample of the clear reddish solution was cooled in a test-tube. A very slight precipitate of unreacted anthraquinone (IX) formed so the reaction was refluxed for 5 minutes more and the solution decanted from the remaining tin (15.0g.: 60% recovered) into a 2-l. beaker;

400cc of ice-water containing 20cc of concentrated hydrochloric acid was added. The precipitate of crude 1-methyl-2-methoxyanthrone-10 (XII) was allowed to granulate for 20 minutes, was filtered off and washed with water. The crude yield of light brown colored anthrone (XII) was 7.9g. (84%); the melting-point was 151° - 153° uncorr. When the filtrate was diluted by an equal volume of water a further precipitate of 0.8g. of anthrone (XII), which melted at 136° - 141° uncorr., was obtained overnight. The total crude yield of XII was 8.7g. (92%).

The first crop of 7.9g. of anthrone was refluxed in 60cc of methanol and the mixture was filtered while hot; a residue of 6.1g. (65%) of grey anthrone (XII) was left which melted at 157° - 161° uncorr. A further 0.9g. of brown anthrone (XII), which melted at 148° - 151° uncorr., precipitated after 10 minutes and was filtered off. The filtrate was evaporated to dryness; the grey residue in the beaker weighed 0.4g. and melted at 153° uncorr. (flowed at 162° uncorr.).

Kurt Meyer reduction differs from Liebermann reduction in the use of a much more concentrated solution, a larger amount of hydrochloric acid, and a longer reaction time.(81) When 1-methyl-2-methoxyanthraquinone (IX) was reduced by the Kurt Meyer method, 1-methyl-2-methoxyanthrone-10 (XII) was obtained in small yield together with some high-melting material which may be a bimolecular product such as dianthrone since the conditions favor a bimolecular reaction.

Fieser's method of reducing linear polynuclear

quinones to the corresponding hydrocarbons gave poor yields of anthrone (XII) and in some cases, even when the tin was amalgamated, only the starting material (IX) was recovered. (37a)

Reduction by zinc and acetic acid produced a very small amount of the anthrone (XII).

The 1-methyl-2-methoxyanthrone-10 (XII) has not been reported in the literature; when recrystallized to a constant melting-point from methanol and carbon bisulphide it forms light yellow microcrystals which melt at 161° uncorr. The sulphuric acid halochromic solution is a pale yellow with a green fluorescence, and upon dilution with water a white turbidity forms.

Calculated,	C	H
for $C_{16}H_{14}O_2$, %	80.6	5.93
Found, %	77.89	5.83

A small amount of ash remaining after the combustion probably accounts for the low values which are, however, in the correct theoretical proportion.

G Skraup Synthesis of 7-methoxy-8-methylbenzanthrone (XV) (4)

A 1.0g. sample of 1-methyl-2-methoxyanthrone-10 (XII) was added to 20cc of acetic acid which was kept at a temperature of about 75° on the water-bath. Then 3cc of concentrated sulphuric acid was stirred in and caused the solution to turn green in color. Stirring was continued and 1-2cc of freshly distilled acrolein were added to the reaction solution (which

changed from a green to an orange color) in small portions during a period of about 8.75 hours. Forty minutes after the last addition the reaction solution was poured on to about 200g. of cracked ice. The green precipitate was filtered off, washed with water, pressed out, and dried. The dry crude yield was 1.6g. (140%); the melting-point was in the range 250°-255° uncorr.

A 0.7g. sample of the crude product was recrystallized from methanol and yielded a few rosette-shaped crystals of an orange color which in concentrated sulphuric acid formed an orange colored halochromic solution which possessed an intense yellow fluorescence. When the vat was diluted with water a faint yellow turbidity remained.

The yield of orange crystals was not increased. The anthrone (XII) is decomposed by heat below 100° and is charred by sulphuric acid at even lower temperatures. Tin or copper were sometimes added to the reaction solution in order to prevent air-oxidation of the anthrone (XII) to the anthraquinone (IX).

Summary

1 Three new substances have been prepared and analyzed: 4'-methoxy-5'-methylorthobenzylbenzoic acid (VII), 1-methyl-2-methoxyanthrone-9 (X), and 1-methyl-2-methoxyanthrone-10 (XII).

2 The fine-structure of benzanthrone was not determined.

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