88. *The Boric Acid Synthesis of* peri-*Hydroxyanthraquinones.*

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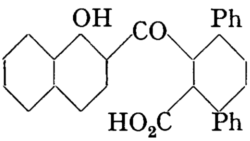
The condensation of simple α-naphthol derivatives and phthalic anhydrides under the influence of boric oxide gives hydroxy-keto-acids, combination taking place in the *o*-position with respect to the phenolic hydroxyl. The reasons for this regularity are discussed, and the differences in behaviour between related hydroxy- and methoxy-compounds emphasised.

In the same way 1 : 4-dihydroxynaphthalene gives dihydroxy-naphthacenequinones and -pentacenequinones with phthalic and naphthalic anhydrides respectively. From hemipinic acid, *e.g.*, 9 : 10-*dihydroxy*-1 : 2-*dimethoxynaphthacene*-11 : 12-*quinone* is obtained, which is easily demethylated, a lake-dye of the naphthacene series being formed.

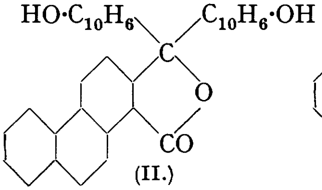
In continuation of our experiments with 3 : 6-diphenylphthalic anhydride (preceding paper) we tried to utilise it for the synthesis of hydroxy-anthraquinones by the method of Weizmann and co-workers (*Ber.*, 1903, **36**, 547, 719; J., 1907, **91**, 411, 1588). Similar experiments were made with other suitable starting materials and the results are reviewed below.

The above anhydride easily condensed with α-naphthol and with 1 : 5-dihydroxynaphthalene monomethyl ether to form the corresponding hydroxy-keto-acids, *e.g.* (I). The hydroxyl and the carboxyl group in (I) could both be methylated by means of diazomethane, and the hydroxyl group was acetylated. No satisfactory method could be devised for the cyclisation of the keto-acids. Apparently, cyclisation is slow and side reactions occur to a remarkable extent. Similar observations have been made with analogous keto-acids (preceding paper); they may be explained by steric hindrance caused by voluminous ortho-substituents. The same may apply to the condensation between phenanthrene-1 : 2-dicarboxylic anhydride and α-naphthol; here the condensation itself is difficult and gives a subsituted *phthalide* (II) instead of the desired hydroxy-keto-acid.

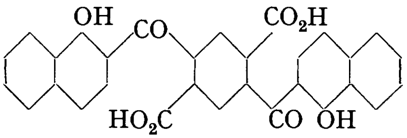
Naphthalene-2 : 3-dicarboxylic anhydride condenses easily with α-naphthol and gives good yields of the expected *keto-acid*, from which the corresponding quinone can be obtained; it has been described by Waldmann (*Ber.*, 1931, **64**, 1722). Pyromellitic anhydride, in the same way, reacts with 2 mols. of α-naphthol, the product obviously being (III) (or the corresponding axial-symmetric isomer). (For the condensation between this anhydride and benzene or toluene, see Philippi, *Monatsh.*, 1911, **32**, 632; Mills and Mills, J., 1912, **101**, 2198. Compare Philippi, *Monatsh.*, 1921, **42**, 1; 1922, **43**, 621; 1924, **45**, 261; Diesbach and Schmidt, *Helv. Chim. Acta*, 1924, **7**, 644.)



(I.)



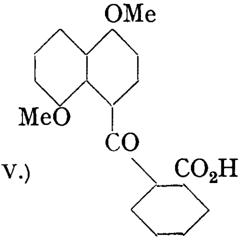
(II.)



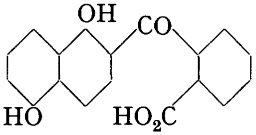
(III.)

Although α-naphthol and its derivatives give a positive response, the boric acid reaction is extremely difficult or even impossible to achieve with phenol and its simple substitution products. Reaction was observed only with the pair phenol and phthalic anhydride, the product being fluoran and not the desired keto-acid.

The location of the hydroxyl group in the newly reported substances is based on the assumption that the carbonyl group enters the *o*-position to phenolic hydroxyl. The same applies certainly to aluminium chloride syntheses. The reason is probably that the primary product is an acid phthalate, which undergoes Fries's transposition and that the *o*-hydroxy-carbonyl compound so formed is stabilised as a complex boric acid derivative. On the other hand, methoxy-groups do not direct the entering acyl radical into the *o*- but rather into the *p*-position (compare Mitter and Dutt, *Chem. Centr.*, 1937, I, 590. For similar observations in the phenanthrene series, see Mosettig and Burger, *J. Amer. Chem. Soc.*, 1933, **55**, 2981; 1934, **56**, 1745). Therefore, the keto-acid, m. p. 263°, obtained by Weizmann and Bergmann (J., 1936, 567) from 1 : 5-dimethoxynaphthalene and phthalic anhydride under the influence of aluminium chloride should be the 1 : 5-dimethoxy-4-*o*-carboxybenzoyl compound (IV), and that reported by Bentley, Friedl, Thomas, and Weizmann (J., 1907, **91**, 411) to be similarly obtained from 1 : 5-dihydroxynaphthalene and phthalic anhydride in presence of boric oxide (m. p. of the dimethyl ether, 209—210°) should be the 2-*o*-carboxybenzoyl derivative (V).



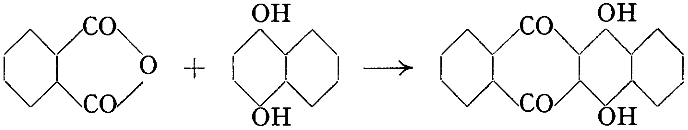
(IV.)



(V.)

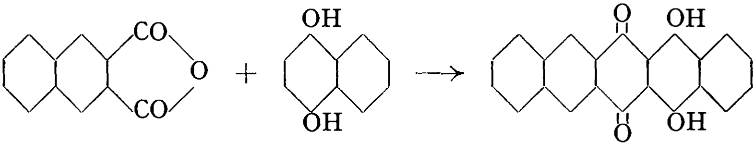
1-Hydroxy-5-methoxynaphthalene on condensation with phthalic anhydride in presence of aluminium chloride gives two isomeric *keto-acids*, the aroyl radical apparently entering in the two possible positions with about equal ease.

The above considerations make it understandable that 1 : 4-dihydroxynaphthalene is converted directly by means of boric acid condensation with phthalic anhydrides into derivatives of dihydroxynaphthacenequinones, *e.g.*,



These reactions proceed smoothly and give excellent yields of the dark red, high-melting dihydroxy-quinones. The analogous reaction, with aluminium chloride–sodium chloride as condensing agent, has been carried out by various authors (Raudnitz, *Ber.*, 1929, **62**, 509, 938; Waldmann and Mathiowetz, *Ber.*, 1931, **64**, 1713; Waldmann, *J. pr. Chem.*, 1931, **131**, 71; Mayer, Stark, and Schoen, *Ber.*, 1932, **65**, 1333. Compare Zahn and Ochwat, *Annalen*, 1928, **462**, 72, and I. G. Farbenindustrie, A.G., D.R.-P., *Chem. Centr.*, 1931, I, 1173).

The following cases have been studied: formation of 9 : 10-dihydroxynaphthacene-11 : 12-quinone with phthalic anhydride, of its 1-*phenyl* and its 1 : 4-*diphenyl* derivative with 3-phenyl- and 3 : 6-diphenyl-phthalic anhydrides, respectively, of 1 : 2 : 3 : 4-*tetrachloro*-9 : 10-*dihydroxynaphthacene*-11 : 12-*quinone* with tetrachlorophthalic anhydride, of 13 : 14-*dihydroxypentacene*-11 : 12-*quinone* with naphthalene-2 : 3-dicarboxylic anhydride,



and of its 9-*phenyl* compound, on starting with 1-phenylnaphthalene-2 : 3-dicarboxylic anhydride. Finally, hemipinic anhydride gave 9 : 10-*dihydroxy*-1 : 2-*dimethoxynaphthacene*-11 : 12-*quinone*. This, on interaction with boiling hydriodic acid, gave the corresponding 1 : 2-*dihydroxy*-compound, which represents the first lake-dye of the naphthacene group.

The tetrachloro-compound differs in colour from the other dihydroxy-quinones. Its crystals are nearly black, whereas all the other representatives of this group, including the dimethoxy-compound, are intensely red. Similar observations have been made before (see also preceding paper, pp. 393, 397).

The intense colour of all these hydroxy-quinones is certainly due to the chelate linkages between the carboxyl and the adjacent hydroxyl groups. The existence of such linkages is also indicated by the fact that diazomethane does not attack the hydroxyl groups, and by the behaviour, reported above, of 9 : 10-dihydroxy-1 : 2-dimethoxynaphthacene-11 : 12-quinone towards hydriodic acid, the quinone system remaining unaffected, whereas usually anthraquinones are easily reduced in these circumstances.

EXPERIMENTAL.

2-(1'-*Hydroxy*-2'-*naphthoyl*)-3 : 6-*diphenylbenzoic Acid* (I).—α-Naphthol (7·2 g.), 3 : 6-diphenylphthalic anhydride (7·5 g.) and boric oxide (7 g.) were thoroughly mixed and heated at 200—220° for 2½ hours. The mass was extracted with boiling water, and the insoluble part dissolved in sodium carbonate solution, filtered, and acidified. The *acid* (I) separated from alcohol in stout prisms, m. p. 150° (decomp. with loss of alcohol of crystallisation); and from toluene in prismatic leaflets, m. p. 214°. Concentrated sulphuric acid gave a brown-red solution, which turned dark blue-green on heating owing to cyclisation and subsequent sulphonation (Found : C, 80·7; H, 4·9. $C_{30}H_{20}O_4$ requires C, 81·1; H, 4·5%). The *acetyl* derivative, crystallised from glacial acetic acid, had m. p. 243° (Found : C, 78·0; H, 5·0. $C_{32}H_{22}O_5$ requires C, 79·0; H, 4·5%).

Methylation with diazomethane produced *methyl* 2-(1'-*methoxy*-2-*naphthoyl*)-3 : 6-*diphenylbenzoate*, m. p. 168° after crystallisation from glacial acetic acid (Found : C, 80·9; H, 4·9. $C_{32}H_{24}O_4$ requires C, 81·4; H, 5·1%).

2-(1'-*Hydroxy*-5'-*methoxy*-2'-*naphthoyl*)-3 : 6-*diphenylbenzoic acid* was obtained by treating a mixture of 1-hydroxy-5-methoxynaphthalene (Fischer and Bauer, *J. pr. Chem.*, 1916, **94**, 15) (4·5 g.), boric oxide (3·5 g.), and 3 : 6-diphenylphthalic anhydride (4·5 g.) as described above and was recrystallised from alcohol; m. p. 210° (sintering at 205°). Concentrated sulphuric acid gave a dark blue solution, turning red after some minutes (Found : C, 78·1; H, 4·1. $C_{31}H_{22}O_5$ requires C, 78·5; H, 4·6%).

Phenanthrene-1 : 2-*dicarboxylic Anhydride*.—The dihydro-derivative (Fieser and Hershberg, *J. Amer. Chem. Soc.*, 1935, **57**, 1853) (5·7 g.) was heated at 300—325° for 10 minutes with sublimed sulphur (0·73 g.). The product was distilled in a vacuum and recrystallised from acetic anhydride : m. p. 311—312°; yield, 5·1 g.

αα-*Di*-(4''-*hydroxy*-1''-*naphthyl*)-3 : 4 : 2' : 1'-*naphthaphthalide* (II).—Phenanthrene-1 : 2-dicarboxylic anhydride (3 g.), α-naphthol (3 g.), and boric oxide (3 g.) were heated at 260° for 2 hours. The *phthalide*, worked up as described above, separated from nitrobenzene in crystals, m. p. 375° (Found : C, 83·8; H, 4·5. $C_{36}H_{22}O_4$ requires C, 83·4; H, 4·2%).

2-(1'-*Hydroxy*-2'-*naphthoyl*)*naphthalene*-3-*carboxylic Acid*.—Naphthalene-2 : 3-dicarboxylic anhydride (10 g.), α-naphthol (10·5 g.), and boric oxide (5 g.) were heated for 2 hours at 200°. The *keto-acid* crystallised from glacial acetic acid or nitrobenzene in rhombohedra, m. p. 256—257° (decomp.), which gave a dark red colour reaction with sulphuric acid (Found : C, 76·6, 76·3; H, 4·2, 4·3. $C_{20}H_{14}O_4$ requires C, 77·2; H, 4·1%).

2 : 5-*Di*-(1'-*hydroxy*-2'-*naphthoyl*)*terephthalic Acid* (? III).—Pyromellitic anhydride (1/20 mol.), α-naphthol (1/5 mol.), and boric oxide (1/5 mol.) reacted only when heated at 300—320° for 4 hours. The product was extracted with water and then with sodium carbonate solution, from which the *keto-acid* was obtained by acidification with boiling hydrochloric acid. The brown powder was reprecipitated in the same way, triturated with alcohol, and crystallised from ethyl malonate–xylene; m. p. 320° (decomp.) (Found : C, 71·0, 70·8; H, 4·1, 4·6. $C_{30}H_{18}O_8$ requires C, 71·2; H, 3·6%).

o-(1' : 5'-*Dimethoxy*-2'-*naphthoyl*)*benzoic Acid*.—A solution of the dihydroxy-acid (3 g., m. p. 231°, Bentley *et al.*, *loc. cit.*, give 221°) in alcohol (50 c.c.) was shaken with potassium hydroxide (3·4 g.) and methyl sulphate (4·4 g.) for 24 hours. After 30 minutes' boiling, the alcohol was distilled off, and the residue dissolved in ether and extracted with sodium carbonate solution. Acidification gave a mixture of acids, which was separated by fractional crystallisation from glacial acetic acid into unchanged material, m. p. 223°, and the desired *dimethoxy-acid*, m. p. 205° after recrystallisation from butyl acetate (Found : OMe, 18·4. $C_{20}H_{16}O_5$ requires OMe, 18·5%).

Phthalic Anhydride and 1-*Hydroxy*-5-*methoxynaphthalene*.—A mixture of phthalic anhydride (3·9 g.) and the naphthalene derivative (5 g.) was added to a solution of aluminium chloride (3·5 g.) in nitrobenzene (50 c.c.). After 24 hours' standing at room temperature and 3 hours' heating at 50°, the mass was decomposed with ice and concentrated hydrochloric acid, and ether added. The ethereal solution was extracted with aqueous sodium carbonate and the acids were precipitated, dried, and recrystallised from toluene in a Dewar vessel. Two *keto-acids* were isolated: one formed long yellow needles, m. p. 221° after recrystallisation from ligroin (Found: C, 70·6; H, 4·6. $C_{19}H_{14}O_5$ requires C, 70·8; H, 4·4%), and the other formed brown clusters, which separated from butyl acetate in lancet-shaped crystals, m. p. 247° (Found: C, 70·4; H, 4·9%).

9 : 10-*Dihydroxynaphthacene*-11 : 12-*quinone*.—1 : 4-Dihydroxynaphthalene (8 g.), phthalic anhydride (11·1 g.), and boric oxide (5·2 g.) were heated at 190° for 2 hours. The hard mass was powdered and washed with hot water. The quinone crystallised from nitrobenzene in red needles (11 g.), m. p. 345°, which dissolved in concentrated sulphuric acid with a purple-red colour [Beilstein, Vol. VIII, p. 482 (Berlin, 1925)].

9 : 10-*Dihydroxy*-1-*phenylnaphthacene*-11 : 12-*quinone*, obtained by the same procedure with 3-phenylphthalic anhydride (preceding paper), crystallised in brilliant red needles, m. p. 290°, from nitrobenzene (yield, 60%). Sulphuric acid gave a cherry-red solution (Found: C, 78·3; H, 3·5. $C_{24}H_{14}O_4$ requires C, 78·7; H, 3·8%).

9 : 10-*Dihydroxy*-1 : 4-*diphenylnaphthacene*-11 : 12-*quinone* (10·5 g.), obtained from 1 : 4-dihydroxynaphthalene (4 g.), 3 : 6-diphenylphthalic anhydride (7·5 g.; preceding paper), and boric oxide (3·5 g.), formed brown-red needles with a violet lustre, m. p. 252·5°, and exhibited a violet sulphuric acid reaction. The best solvent for recrystallisation was butyl alcohol (Found: C, 81·1; H, 4·4. $C_{30}H_{18}O_4$ requires C, 81·4; H, 4·1%).

1 : 2 : 3 : 4-*Tetrachloro*-9 : 10-*dihydroxynaphthacene*-11 : 12-*quinone*, obtained from tetrachlorophthalic anhydride (14·7 g.), 1 : 4-dihydroxynaphthalene (8 g.), and boric acid at 200° (3 hours), crystallised from bromobenzene in brown-black, shiny needles (12 g.), m. p. 327°, which dissolved in sulphuric acid with a violet colour (Found: C, 50·8; H, 2·8. $C_{18}H_6O_4Cl_4$ requires C, 50·7; H, 1·4%).

9 : 10-*Dihydroxy*-1 : 2-*dimethoxynaphthacene*-11 : 12-*quinone*, similarly obtained from 1 : 4-dihydroxynaphthalene (3·2 g.), hemipinic anhydride (2·2 g.), and boric oxide (1·4 g.), was relatively soluble and crystallised from amyl acetate in orange-red, prismatic needles (3·5 g.), m. p. 265°, which formed a blue-red, dichroic solution in concentrated sulphuric acid (Found: C, 68·0; H, 4·4. $C_{20}H_{14}O_6$ requires C, 68·6; H, 4·0%).

Complete demethylation took place after 3 hours' boiling with hydriodic acid (d = 1·76; 10 parts). The dark red, microcrystalline 1 : 2 : 9 : 10-*tetrahydroxynaphthalene*-11 : 12-*quinone* was recrystallised from nitrobenzene and had m. p. 289° (Found: C, 66·6; H, 3·5. $C_{18}H_{10}O_6$ requires C, 67·1; H, 3·1%).

13 : 14-*Dihydroxypentacene*-11 : 12-*quinone*, after reaction between naphthalene-2 : 3-dicarboxylic anhydride (3 g.), 1 : 4-dihydroxynaphthalene (4·8 g.), and boric oxide (2·1 g.) at 190° for 2 hours, was obtained as a powder, which crystallised from nitrobenzene in red needles (3 g.), m. p. 360°, and developed a deep blue-red colour in sulphuric acid (Found: C, 76·8; H, 4·0. $C_{22}H_{12}O_4$ requires C, 77·6; H, 3·5%).

13 : 14-*Dihydroxy*-9-*phenylpentacene*-11 : 12-*quinone*, obtained from 1-phenylnaphthalene-2 : 3-dicarboxylic anhydride (Michael and Bucher, *Ber.*, 1906, **39**, 1911; 1908, **41**, 70) (3·5 g.), 1 : 4-dihydroxynaphthalene (4 g.), and boric oxide (1·7 g.) at 190°, and crystallised from nitrobenzene and then from bromobenzene, formed bordeaux-red needles, m. p. 359°. In sulphuric acid it formed a red-blue dichroic solution (Found: C, 81·7, 81·6; H, 4·4, 4·5. $C_{28}H_{16}O_4$ requires C, 80·8; H, 3·9%).

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