474. *Chemistry of Indanthrone. Part V.** tert.-*Butyl Derivatives of Indanthrone and Flavanthrone. The Mode of Formation of Flavanthrone in the Alkali Fusion of 2-Aminoanthraquinone.*

By William Bradley and Harry E. Nursten.

The course of chemical change is frequently modified by the presence of bulky alkyl groups in one or more of the reactants. Fused with potassium hydroxide at 240°, 2-aminoanthraquinone yields indanthrone; at 300° the main product is flavanthrone. 2-Amino-3-*tert.*-butylanthraquinone yielded 3 : 3′-di-*tert.*-butylflavanthrone at both of these temperatures; there was no indication of the formation of 3 : 3′-di-*tert.*-butylindanthrone or the related azine. The indanthrone was prepared by the self-condensation of 2-amino-1-bromo-3-*tert.*-butylanthraquinone. The reaction yielded also the corresponding azine and flavanthrone. The formation of a flavanthrone derivative in a reaction of the kind described is very unusual.

Di-*tert.*-butylindanthrone is less stable than indanthrone towards dehydrogenation to an azine. The result accords with the known effect of alkyl groups in facilitating the dehydrogenation of 1 : 4-dihydroxynaphthalene to α-naphthaquinone. There is no evidence for a steric effect of *tert.*-butyl groups which restrains the dehydrogenation of indanthrone to indanthroneazine.

The mode of formation of flavanthrone in the alkali fusion of 2-aminoanthraquinone is discussed.

The 3 : 3′-di-*tert.*-butyl derivatives of indanthrone, indanthroneazine, and flavanthrone were prepared from *tert.*-butylbenzene. This was condensed with phthalic anhydride, and the product was nitrated, reduced, and cyclised to give 2-amino-3-*tert.*-butylanthraquinone amongst other products.

Many examples have been recorded of the effects of *o-tert.*-butyl substituents on the physical and chemical properties of organic compounds (Brown and Reagan, *J. Amer. Chem. Soc.*, 1947, **69**, 1032; Remington, *ibid.*, 1945, **67**, 1838; Brown and Cahn, *ibid.*, 1950, **72**, 2939). It was considered of interest, therefore, to prepare 3 : 3′-di-*tert.*-butylindanthrone (IX). Molecular models showed that neighbouring imino- and *tert.*-butyl groups approached sufficiently closely in this compound for the bulky alkyl groups to modify the properties of the dihydroazine nucleus.

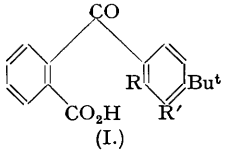
In preparing (IX) *o-p′-tert.*-butylbenzoylbenzoic acid (I; R = R′ = H) was obtained by Peters and Rowe's method (*J.*, 1945, 181) and then nitrated. Boiling nitric acid afforded a mixture of two isomeric mononitro-derivatives together with phthalic acid and *p-tert.*-butylnitrobenzene. A somewhat similar fission during nitration was observed by Legge (*J. Amer. Chem. Soc.*, 1947, **69**, 2086) who obtained *p-tert.*-butylnitrobenzene as a product of nitrating *p*-di-*tert.*-butylbenzene. The replacement of *p*-acyl by nitro-groups in the nitration of substituted amines and phenol ethers is not uncommon (Nightingale, *Chem. Reviews*, 1947, **40**, 117; van Romburgh, *Rec. Trav. chim.*, 1887, **6**, 367) but the analogous replacement of a *p*-acyl group in a derivative of *tert.*-butylbenzene has not been recorded previously. The result illustrates the marked electron-releasing character of the *tert.*-butyl group.

When a mixture of nitric and sulphuric acid was used in the nitration the formation of *p-tert.*-butylnitrobenzene was not observed. The product was almost wholly a mononitro-derivative, m. p. 203·5—204·5°. The same derivative and, in addition, an isomer, m. p. 187—188°, were formed by concentrated nitric acid alone. On reduction each nitro-derivative yielded the corresponding amine. That from the nitro-derivative of lower m. p. readily afforded a lactam. This was considered to have the structure (III), and hence the intermediate nitro- and amino-acids were *o*-(4-*tert.*-butyl-2-nitrobenzoyl)benzoic acid (II) and *o*-(2-amino-4-*tert.*-butylbenzoyl)benzoic acid (I; R = NH_2, R′ = H). The isomeric nitro-acid was considered to be *o*-(4-*tert.*-butyl-3-nitrobenzoyl)benzoic acid (IV), and the related amine *o*-(3-amino-4-*tert.*-butylbenzoyl)benzoic acid (I; R = H, R′ = NH_2). The last two structures are supported by the following considerations. Phthalic acid is not nitrated when it is heated with boiling nitric acid; this suggests that in the present instance nitration has been confined to the nucleus

* Part IV, preceding paper.

carrying the *tert.*-butyl group. The amine (I; R = H, R′ = NH_2) can be diazotised and the resulting diazonium salt coupled to β-naphthol, but the diazonium salt is unusually unstable; in this respect it resembles the diazonium salt from *o-tert.*-butylaniline. The amine (I; R = NH_2, R′ = H) affords a diazonium salt having normal stability. In this it resembles *m*- and *p-tert.*-butylanilines (Shoesmith and Mackie, *J.*, 1928, 2334).

The cyclisation of (I; R = H, R′ = NH_2) to a derivative of anthraquinone occurred only with difficulty. Heating alone, or in a neutral solvent, or with phosphoric oxide, failed to bring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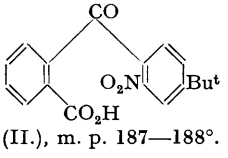
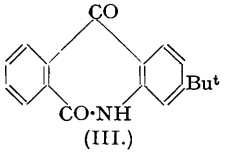

(II.), m. p. 187—188°.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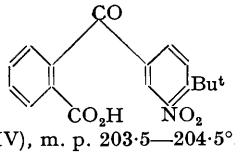
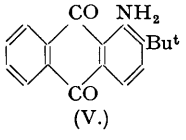

(IV), m. p. 203·5—204·5°.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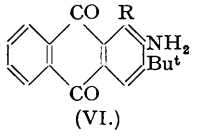
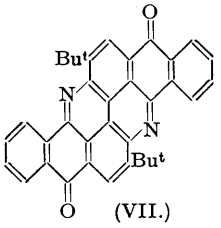

(VI.)

about ring closure. Heating with phosphorus pentachloride (cf. Scholl and Neovius, *Ber.*, 1911, **44**, 1075) gave an anthraquinone derivative in extremely small yield. The most practical method was to employ concentrated sulphuric acid. This reagent afforded 1-amino-2-*tert.*-butylanthraquinone (V) identical with Moualim and Peters's compound (*J.*, 1948, 1627) prepared by reducing 2-*tert.*-butyl-1-nitroanthraquinone. The result confirms the structures (IV) and (I; R = H, R′ = NH_2). In addition, 2-amino-3-*tert.*-butylanthraquinone (VI; R = H) was formed. The constitution of this compound rests on its composition, mode of derivation, and difference from (V). The yields of (V) and (VI; R = H) were 12% and 16%, respectively. A longer period of heating with sulphuric acid led to formation of 2-aminoanthraquinone in small amount.

Although 2-aminoanthraquinone is easily brominated to form 2-amino-1 : 3-dibromoanthraquinone (Scholl, *Ber.*, 1907, **40**, 1700), yet 2-amino-3-*tert.*-butylanthraquinone forms a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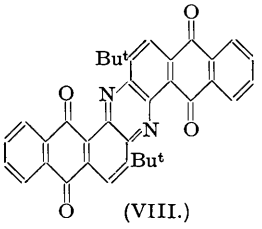
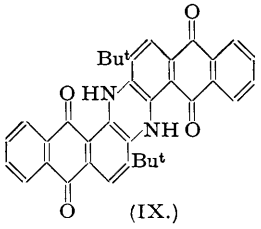

(VIII.)


(IX.)

bromo-derivative with difficulty, when bromine is used as the brominating agent. The result was first considered to be a further illustration of the effect of an *o-tert.*-butyl substituent in restraining nuclear substitution. It is more probable, however, that the bromine substituent, once introduced, is easily eliminated in the presence of hydrogen bromide. By use of *N*-bromosuccinimide (Ziegler *et al.*, *Annalen*, 1942, **551**, 80) 2-amino-1-bromo-3-*tert.*-butylanthraquinone (VI; R = Br) was obtained in 57% yield.

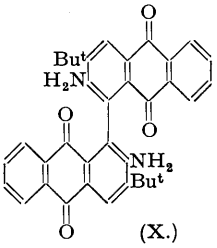
Heating 2-amino-3-*tert.*-butylanthraquinone with potassium hydroxide at 300° afforded 3 : 3′-di-*tert.*-butylflavanthrone (VII) in 65% yield. At 220° appreciable quantities of (VII) were again formed, but there was no indication of the presence of the related 3 : 3′-di-*tert.*-butylindanthrone (IX) or of the corresponding azine (VIII).

The result indicates that the 3-*tert.*-butyl substituent of 2-amino-3-*tert.*-butylanthraquinone prevents the formation of the indanthrone derivative or that this derivative is unstable, or finally that the formation of the flavanthrone is favoured. Several observations have been made which bear on these points.

The dehydrogenation of 3 : 3′-di-*tert.*-butylindanthrone (IX) to the related azine (VIII) occurred quite readily, particularly in the presence of copper salts. Even on exposure to light, a solution of (IX) in chlorobenzene slowly became green. The change, azine (VIII) $\xrightarrow{+2H}$

dihydroazine (IX), occurred evidently on heating alone above 250°; it occurred also on heating with quinoline at the boiling point. 3 : 3′-Di-*tert.*-butylindanthrone is evidently less stable towards dehydrogenation than is indanthrone. Fieser and Fieser (*J. Amer. Chem. Soc.*, 1935, **57**, 491) have shown that the introduction of a methyl substituent into α-naphthaquinone enhances the stability of the quinone against reduction, and that carbonyl and halogen groups on the contrary stabilize the corresponding quinol against oxidation. Scholl (*Ber.*, 1903, **36**, 3410) recognized that the unusual stability of indanthrone, a dihydroazine, was dependent on the presence of four carbonyl groups, and that the stability could be enhanced by introducing halogen substituents. It would be expected therefore that alkyl substituents should reduce the stability of dihydroazines. In 3 : 3′-di-*tert.*-butylindanthrone the combined effect of two such groups is sufficient to make the dehydrogenation of (IX) to the azine (VIII) an easy process. The result may be explained by the marked electron-releasing character of *tert.*-alkyl groups, and this effect may be augmented by a tendency to overcome the interference between the *tert.*-butyl groups and the dihydroazine nucleus to which reference has been made.

In experiments designed to yield 3 : 3′-di-*tert.*-butylindanthrone (IX), 2-amino-1-bromo-3-*tert.*-butylanthraquinone (VI; R = Br) was heated with copper acetate and anhydrous sodium acetate in boiling *o*-dichlorobenzene. Several compounds were isolated from the product. These were : (*a*) A red compound, probably 2 : 2′-diamino-3 : 3′-di-*tert.*-butyl-1 : 1′-dianthraquinonyl (X), which passed rapidly into the bright yellow 3 : 3′-di-*tert.*-butylflavanthrone (VII)



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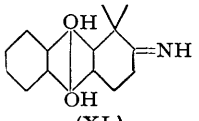


(XI.)

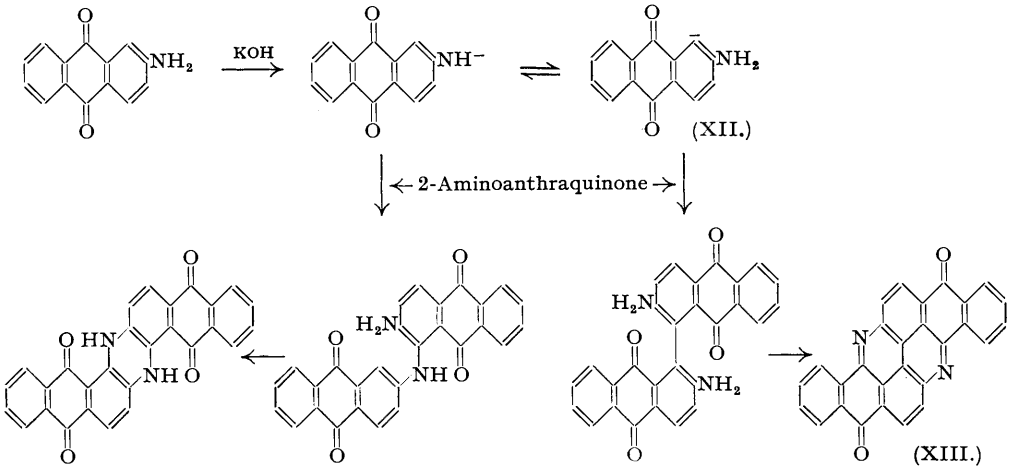
on contact with alkali or exposure to air. In this respect it resembled Scholl and Dischendorfer's red 2 : 2′-diamino-1 : 1′-dianthraquinonyl (*Ber.*, 1918, **51**, 452) which similarly easily yielded flavanthrone. (*b*) 3 : 3′-Di-*tert.*-butylflavanthrone (VII). The formation of a flavanthrone derivative by the self-condensation of a 2-amino-1-bromoanthraquinone has been reported only on one previous occasion. In D.R.-P. 172,733 it was claimed that flavanthrones result, possibly mixed with small quantities of indanthrones, when 2-amino-1 : 3-dibromo(or 1 : 3-dichloro)-anthraquinones are heated with a metallic salt and an alkali hydroxide or sodamide. (*c*) 3 : 3′-Di-*tert.*-butylindanthroneazine (VIII). (*d*) 3 : 3′-Di-*tert.*-butylindanthrone (IX).

The products were separated by chromatography. When the reaction had proceeded for 4 hours, (*a*), (*c*), and (*d*) were recognized, and from these (*b*) and additional amounts of (*c*) were formed on exposure to air. After 6 hours, (*b*), (*c*), and (*d*) were isolated, and after 24 hours only (*b*) and (*c*).

The introduction of two *tert.*-butyl groups into the molecules of indanthrone and flavanthrone causes other interesting changes in properties. Both 3 : 3′-di-*tert.*-butyl-indanthrone and -flavanthrone are much more soluble in organic solvents than are indanthrone and flavanthrone. The same effect of alkyl groups was reported by Bradley and Leete (*J.*, 1951, 2136) as the result of *N*-methylating indanthrone. The change in solubility was there ascribed to the effect of methylation in preventing the association of molecules of indanthrone, but the greater solubility of di-*tert.*-butylflavanthrone can only depend on a positive contribution by the *tert.*-butyl groups. 3 : 3′-Di-*tert.*-butylflavanthrone is less easily reduced than flavanthrone, a result which accords with Fieser and Fieser's work (*loc. cit.*) on the reduction of substituted α-naphthaquinones.

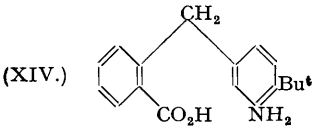
The formation of 3 : 3′-di-*tert.*-butylflavanthrone by the alkali fusion of 2-amino-3-*tert.*-butylanthraquinone at 220°, when 3 : 3′-di-*tert.*-butylindanthrone would be expected, raises the question how flavanthrones are formed by the alkali fusion of 2-aminoanthraquinones. Bohn's discovery of flavanthrone as a product of the alkali fusion of 2-aminoanthraquinone (D.R.-P. 133,686; Scholl, *Ber.*, 1907, **40**, 1691) was explained by Scholl (*loc. cit.*) as the result of the dehydrogenation of two molecules of 2-aminoanthraquinone to form 2 : 2′-diamino-1 : 1′-dianthraquinonyl. Schwenk (*Chem. Ztg.*, 1928, **52**, 45) held that 2-aminoanthraquinone and alkali yielded the radical (XI), which then polymerised to yield flavanthrone (XIII). An

acceptable view of the mechanism of the formation of flavanthrone from 2-aminoanthraquinone by the action of alkalis, however, must take account of the fact that indanthrone- and flavanthrone-formation are simultaneous reactions (Bohn, *loc. cit.*), and that for this reason they probably originate in the same primary process. Bradley and Leete (*loc. cit.*) have



(XII.) (XIII.)

suggested that the formation of indanthrone begins with the ionisation of 2-aminoanthraquinone, followed by the union of the anion with a second molecule of the amine. It appears probable that the formation of flavanthrone originates in the same process of ionisation, the anion reacting with the second molecule of 2-aminoanthraquinone in the form (XII). The formation of both a *C*- and an *N*-derivative by the reaction of the anion of 2-aminoanthraquinone with a molecule of 2-aminoanthraquinone is not unexpected (see Waters, " Physical Aspects of Organic Chemistry," Routledge and Kegan Paul Ltd., London, 4th Edition, p. 436). Alkylation of potassiopyrrole affords both *N*- and *C*-derivatives of pyrrole (Llubawin, *Ber.*, 1869, **2**, 101; Bell, *Ber.*, 1878, **11**, 1810; Ciamician and Dennstedt, *Ber.*, 1882, **15**, 2581; Ciamician and Silber, *Ber.*, 1887, **20**, 1369; Ciamician and Zanetti, *Ber.*, 1889, **22**, 659; Zanetti,



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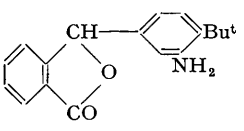

(XV.)

ibid., p. 2518). Similarly, the sodio-derivative of indole when heated with methyl iodide affords 2- and 3-methylindole as well as *N*-methylindole (Weissgerber, *Ber.*, 1910, **43**, 3521).

At an early stage in the present work an attempt was made to obtain 2-amino-3-*tert.*-butylanthraquinone in better yield by first preparing the corresponding anthrone by cyclising the acid (XIV). Reduction of *o*-(3-amino-4-*tert.*-butylbenzoyl)benzoic acid (I; R = H, R′ = NH_2) by means of amalgamated zinc and hydrochloric acid gave the corresponding phthalide (XV), and this was almost unaffected when heated with zinc dust in aqueous sodium hydroxide (cf. Ullmann, *Annalen*, 1896, **291**, 17). Reduction of (I; R = H, R′ = NH_2) by ammonia, zinc dust, and copper sulphate (cf. Elbs, *J. pr. Chem.*, 1890, **41**, 121; Fieser and Newman, *J. Amer. Chem. Soc.*, 1936, **58**, 2376) afforded a product which contained much of the phthalide. Heating with hydrazine and the sodium salt of glycol yielded a phthalazine derivative (cf. Bergman and Pinchas, *J. Org. Chem.*, 1950, **15**, 1023).

Experimental.

Methyl o-p′-tert.-*Butylbenzoylbenzoate.*—*o-p′-tert.*-Butylbenzoylbenzoic acid was prepared by Peters and Rowe's method (*J.*, 1945, 181). Reaction was relatively slow; the yield of crude acid was 49% after 8 hours and 67% after 16 hours. Crystallisation from benzene–ligroin gave colourless plates, m. p. 152—153° (Peters and Rowe, *loc. cit.*, record m. p. 148—149°). The *methyl* ester, prepared by diazomethane, crystallised from methyl alcohol in large prisms, m. p. 69—70° (Found : C, 76·8; H, 6·7. $C_{19}H_{20}O_3$ requires C, 77·0; H, 6·8%). The same ester, m. p. 70—71° (Found : C, 76·9; H, 7·1%), was obtained in a yield of 0·5 g. when *o-p′-tert.*-butylbenzoylbenzoic acid (1 g.) was heated under reflux for

4 hours with concentrated hydrochloric acid (25 c.c.) and methyl alcohol (20 c.c.). There was no indication of the formation of *tert.*-butylbenzene in this preparation.

Nitration of o-p'-tert.-*Butylbenzoylbenzoic Acid.*—(*a*) The acid was unaffected by concentrated or fuming nitric acid in acetic acid at 100°.

(*b*) A mixture or concentrated nitric acid (7·3 c.c.) and concentrated sulphuric acid (75 c.c.) was added to a solution containing *o-p'-tert.*-butylbenzoylbenzoic acid (30 g.) in concentrated sulphuric acid (200 c.c.) at $\not>35°$. The solution was then kept for an hour and added to water. The precipitate was collected, dissolved in aqueous sodium carbonate (charcoal), and then recovered by acidification. A mononitration product, m. p. *ca.* 190°, obtained in almost quantitative yield, consisted almost entirely of the 3'-nitro-derivative. o-(4-tert.-*Butyl*-3-*nitrobenzoyl*)*benzoic acid* crystallises from toluene in small plates, m. p. 203·5—204·5°, softening at 195° (Found : C, 66·2; H, 5·2; N, 4·3. $C_{18}H_{17}O_5N$ requires C, 66·1; H, 5·2; N, 4·3%). It was recovered unaltered after being heated in boiling 5% aqueous sodium hydroxide for 5 hours. *Methyl* o-(4-tert.-*butyl*-3-*nitrobenzoyl*)*benzoate*, crystallised from methyl alcohol, had m. p. 129·5—130·5° (Found : C, 66·8; H, 5·6; N, 4·35. $C_{19}H_{19}O_5N$ requires C, 66·85; H, 5·6; N, 4·1%).

(*c*) When the nitration was carried out by adding 5 c.c. of fuming nitric acid to a solution containing 3·6 g. of *o-p'-tert.*-butylbenoylbenzoic acid in concentrated sulphuric acid (15 c.c.), and the product was heated at 95° for 2 hours, a tarry product slowly separated. There was no evidence of the formation of *p-tert.*-butylnitrobenzene (steam-distillation). Addition of ether caused the separation of a yellowish powder (1·25 g.), and this, recrystallised from aqueous acetic acid, afforded colourless needles, m. p. 240—241° (Found : C, 52·1; H, 4·0; N, 9·9. $C_{18}H_{15}O_9N_3$ requires C, 51·8; H, 3·6; N, 10·1%), of a 2-p-tert.-*butylbenzoyltrinitrobenzoic acid.*

(*d*) A solution containing *o-p'-tert.*-butylbenzoylbenzoic acid (20 g.) in concentrated nitric acid (100 c.c.) was heated under reflux for 30 minutes, then cooled and filtered; the residue (17·2 g.) had m. p. 165—175°. The mother-liquor yielded 4 g. of material, m. p. 165—175° (decomp.). The main fraction, crystallised from benzene and then from toluene, afforded *o*-(4-*tert.*-butyl-3-nitrobenzoyl)benzoic acid (7·3 g.), identical with that described under (*b*). The mother-liquors afforded 5·5 g. of material, m. p. 176—179°. After this had been separated and the liquor evaporated to dryness, an oil remained. The oil was mixed with dilute sodium carbonate solution and distilled in steam. The colourless distillate (*ca.* 2 c.c.) was heated for 3 hours with an excess of dilute acetic acid and iron filings (5 g.). The product was distilled in steam and the oily distillate was shaken with acetic anhydride; colourless crystals of *p-tert.*-butylacetanilide, m. p. 172—173°, separated. The m. p. was unchanged by authentic material (Legge, *J. Amer. Chem. Soc.*, 1947, **69**, 2086, records m. p. 174·6—175·2°). When the oily distillate was shaken with benzoyl chloride and an excess of dilute sodium hydroxide, *p-tert.*-butylbenzanilide separated having m. p. 142·5—143·5° not depressed by mixing with authentic material (Legge, *loc. cit.*, records m. p. 143·1—143·7°) (Found : C, 80·5; H, 7·2; N, 5·3. Calc. for $C_{17}H_{19}ON$: C, 80·6; H, 7·5; N, 5·5%).

The second fraction, m. p. 165—175° (decomp.), extracted with toluene, afforded a colourless residue (0·75 g.). This melted with decomposition at 197—200°, solidified immediately on cooling, and when reheated melted at 129°. Crystallisation from acetic acid afforded colourless prisms and these, sublimed *in vacuo*, gave phthalic anhydride, m. p. 130·5—131·5°. The toluene extract afforded a product on cooling. This, recrystallised several times from benzene, gave colourless plates of o-(4-tert.-*butyl*-2-*nitrobenzoyl*)*benzoic acid*, m. p. 187—188°, with previous sintering (Found : C, 66·4; H, 5·3; N, 4·25%). A mixture with the isomer, m. p. 203·5—204·5°, melted below 180°.

o-(3-*Amino*-4-tert.-*butylbenzoyl*)*benzoic Acid.*—A solution containing *o*-(4-*tert.*-butyl-3-nitrobenzoyl)-benzoic acid (6 g.) in aqueous ammonia (75 c.c.) was boiled for 15 minutes with ferrous hydroxide, prepared by adding aqueous ammonia (70 c.c.) to a solution of hydrated ferrous sulphate (40 g.) in water (300 c.c.). The resulting suspension was filtered, and the filtrate boiled to expel ammonia and then acidified with acetic acid. An oil separated and this solidified, forming a pale yellow powder (5·4 g.), m. p. 213—216° (decomp.). Repeated crystallisation from toluene afforded almost colourless leaflets of o-(3-*amino*-4-tert.-*butylbenzoyl*)*benzoic acid*, m. p. 218—219° (decomp.) (Found : C, 72·7; H, 6·5; N, 4·9. $C_{18}H_{19}O_3N$ requires C, 72·7; H, 6·4; N, 4·7%). Reduction of the nitro-acid by iron and acetic acid or sodium dithionite (hydrosulphite) in aqueous alkali or alcohol gave less satisfactory results.

The amino-acid could be diazotised below 0°; the diazonium salt coupled to alkaline β-naphthol to form an orange-red solution. Titration with standard sodium hydroxide indicated a molecular weight of 291 (Calc. for $C_{18}H_{19}O_3N$: *M*, 297). It was almost insoluble in concentrated hydrochloric acid, and no apparent change was caused by heating it with this reagent for 4 hours. It dissolved in 14% hydrochloric acid; after the solution had been boiled for 4 hours almost colourless needles separated. These consisted of the *hydrochloride* of o-(3-*amino*-4-tert.-*butylbenzoyl*)*benzoic acid* (Found : Cl^-, 9·4. $C_{18}H_{20}O_3NCl$ requires Cl^-, 10·6%). The hydrochloride softened at 200°, became red-brown, and finally decomposed without melting at 250°; it was soluble in cold 5% aqueous sodium carbonate (absence of lactam; cf. Kränzlein, *Ber.*, 1937, **70**, 1952). The product of thermal decomposition was insoluble in either hot 5% sodium hydroxide or hot 18% hydrochloric acid; a similar red-brown product resulted when the amino-acid was heated under reflux in *o*-dichlorobenzene for 40 minutes.

Methyl o-(3-*amino*-4-tert.-*butylbenzoyl*)*benzoate* was obtained as almost colourless prisms, m. p. 122—123° (Found : C, 73·3; H, 6·9; N, 4·2. $C_{19}H_{21}O_3N$ requires C, 73·3; H, 6·8; N, 4·5%), by esterifying the amino-acid with methanol and sulphuric acid. The identical product was obtained by reducing methyl *o*-(4-*tert.*-butyl-3-nitrobenzoyl)benzoate by iron and dilute acetic acid.

o-(2-*Amino*-4-tert.-*butylbenzoyl*)*benzoic acid* was prepared by reducing the 2'-nitro-acid with ammoniacal ferrous hydroxide. The filtrate afforded yellow crystals which decomposed at 130—140°. Dissolved in water and acidified, these yielded an acid which crystallised from benzene–ligroin in pale yellow plates, m. p. 176—177° (decomp.) (Found : C, 73·45; H, 6·2; N, 5·4%). The product consisted

essentially of *o*-(2-amino-4-*tert.*-butylbenzoyl)benzoic acid (yield, 50%). It diazotised readily; the diazonium salt afforded an orange solution when added to alkaline β-naphthol. Heated under reflux for 3 hours with 10 c.c. of 21% hydrochloric acid, the amino-acid (0·05 g.) gave, almost immediately, colourless, small plates (0·035 g.), which crystallised from aqueous alcohol in needles, m. p. 182·5—183·5° (Found: C, 76·45; H, 5·6; N, 4·8. $C_{18}H_{17}O_2N$ requires C, 77·4; H, 6·1; N, 5·0%). The composition of the product indicated that it was essentially the *lactam*.

3′-*Amino*-4′-tert.-*butylphenylphthalide*.—*o*-(3-Amino-4-*tert.*-butylbenzoyl)benzoic acid (1·4 g.), heated for 3 hours with amalgamated zinc (4 g.) and concentrated hydrochloric acid (25 c.c.), afforded an insoluble oil. Water was added, then sodium carbonate to neutrality; finally the suspension was extracted by means of ether. The evaporated extract afforded a brown solid (0·7 g.), and this was extracted by hot 5% aqueous sodium carbonate, and the residue crystallised from alcohol. Colourless crystals of the *phthalide* separated, having m. p. 139—140° (Found: C, 76·8; H, 7·0; N, 4·8. $C_{18}H_{19}O_2N$ requires C, 76·9; H, 6·8; N, 5·0%). This phthalide (m. p. 139—140°; 0·6 g.) also resulted when 2 g. of the amino-acid in 50 c.c. of dilute aqueous ammonia were heated under reflux for 56 hours with zinc dust (4 g.) and copper sulphate (0·5 g.), successive portions of ammonia being added every 2 hours. In this experiment the alkaline solution from which the phthalide had separated was filtered, acidified by means of acetic acid, and then extracted by means of ether. The extract yielded a tarry residue on evaporation; this was soluble in aqueous sodium carbonate. The filtered extract on acidification yielded 0·5 g. of a solid. Recrystallisation of this from benzene–ligroin afforded a small quantity of colourless needles, m. p. 115—116° (Found: C, 75·5; H, 6·9. $C_{18}H_{21}O_2N$ requires C, 76·3; H, 7·4%), which consisted essentially of o-(3-*amino*-4-tert.-*butylbenzyl*)*benzoic acid*. This *acid* dissolved in concentrated sulphuric acid with a yellow colour. When heated to 100° the solution became wine-red. According to Scholl and Neovius (*loc. cit.*), *o*-benzylbenzoic acid undergoes a similar change at 140°.

The phthalide was recovered unchanged after 4 hours' heating under reflux with zinc dust and 5% aqueous sodium hydroxide.

1-(3-*Amino*-4-tert.-*butylphenyl*)-4-*hydroxyphthalazine*.—*o*-(3-Amino-4-*tert.*-butylbenzoyl)benzoic acid (0·5 g.), heated with hydrazine under the conditions described by Huang-Minlon (*J. Amer. Chem. Soc.*, 1946, **68**, 2487), afforded 0·41 g. of an almost colourless powder, m. p. 278—280°. It was insoluble in aqueous sodium hydroxide or alcohol; it dissolved in concentrated hydrochloric acid. Crystallisation from toluene gave colourless platelets of the *phthalazine*, m. p. 278—280° (Found: C, 73·5; H, 6·2; N, 14·6. $C_{18}H_{19}ON_3$ requires C, 73·7; H, 6·5; N, 14·3%). Bergmann and Pinchas (*J. Org. Chem.*, 1950, **15**, 1023) have described an analogous product from 4-*o*-carboxybenzoyldiphenyl.

1-*Amino*-2-tert.-*butyl- and* 2-*Amino*-3-tert.-*butyl-anthraquinone*.—A solution containing *o*-(3-amino-4-*tert.*-butylbenzoyl)benzoic acid (5 g.) in concentrated sulphuric acid (50 c.c.) was heated at 155—160° for 10 minutes, then cooled and added to water. The dark brown precipitate (3·6 g.) was collected, washed, dried, and then extracted with benzene; there was a brown residue (1·3 g.). The solution was passed through a column of alumina. Several bands formed. The most mobile was orange-red; elution with benzene and recovery yielded a red powder (0·55 g.; m. p. 145—152°), which, recrystallised from aqueous acetic acid, gave red needles, m. p. 159—160°, not depressed on admixture with an authentic sample of 1-amino-2-*tert.*-butylanthraquinone, m. p. 160—161° (kindly provided by Dr. A. T. Peters), which had been prepared by the method of Moualim and Peters (*J.*, 1948, 1627).

The second, orange band was eluted by acetone. The extract was concentrated and then ligroin was added. On cooling, 0·74 g. of orange-yellow needles separated, having m. p. 203—205°. Recrystallisation from benzene gave pure 2-*amino*-3-tert.-*butylanthraquinone*, m. p. 205—205·5° (Found: C, 77·0; H, 6·2; N, 4·9. $C_{18}H_{17}O_2N$ requires C, 77·4; H, 6·1; N, 5·0%).

The chromatogram showed several fainter zones; there was also a strongly adsorbed dark red-brown band. When the time occupied by the ring closure was 20 minutes, a second and less mobile orange band appeared on the column. Elution by acetone and evaporation of the extract gave orange needles, m. p. 309—310°. Heating with acetic anhydride transformed these into yellow plates, m. p. 266—267°, not depressed on admixture with authentic 2-acetamidoanthraquinone.

o-(3-Amino-4-*tert.*-butylbenzoyl)benzoic acid was recovered almost unaltered after 2 hours' heating with concentrated sulphuric acid or 10% oleum at 95°, or after being dissolved in 20% oleum and kept at room temperature for 12 hours. Heating alone at 230° for 7 minutes, or with 75% sulphuric acid at 200°, or with phosphoric oxide in chlorobenzene gave none of the desired product. A small yield was obtained by heating the amino-acid with phosphorus pentachloride in boiling chlorobenzene for 3 hours.

2-Amino-3-*tert.*-butylanthraquinone formed a yellow solution in sulphuric acid. Alkaline sodium dithionite dissolved it, forming a red solution. Its orange solution in pyridine became reddish-brown on addition of methyl-alcoholic potassium hydroxide; the original colour was regenerated on addition of methanol. It formed a yellow solution in acetic anhydride and this became colourless when heated with boroacetic anhydride. There was no indication of the formation of a flavanthrone derivative when 2-amino-3-*tert.*-butylanthraquinone was heated with antimony pentachloride in nitrobenzene. The absorption spectrum of a solution in benzene was closely similar to that of 2-aminoanthraquinone in the same solvent.

1-Amino-2-*tert.*-butylanthraquinone formed orange solutions in both sulphuric acid and alkaline sodium dithionite. Addition of boroacetic anhydride to its orange solution in acetic anhydride caused a change in colour to bluish-red; the solution showed a strong red-violet fluorescence in ultra-violet light. The orange solution in pyridine was unchanged on addition of methyl-alcoholic potassium hydroxide. Heating for 2 hours at 100° with benzoyl chloride containing a few drops of concentrated sulphuric acid afforded 1-*benzamido*-2-tert.-*butylanthraquinone*, which crystallised from dilute acetic acid in yellow needles, m. p. 250—250·5° (Found: C, 77·5; H, 5·5; N, 3·8. $C_{25}H_{21}O_3N$ requires C, 78·3; H, 5·5; N, 3·7%). A solution in benzene showed maximum light absorption at 4800 Å; a similar solution of 1-aminoanthraquinone showed a maximum at 4650 Å.

2-*Amino*-1-*bromo*-3-tert.-*butylanthraquinone*.—A solution containing 2-amino-3-*tert*.-butylanthraquinone (0·48 g.) in carbon tetrachloride (50 c.c.) was heated under reflux for 5 hours with *N*-bromosuccinimide (0·31 g.), then cooled, and the precipitated succinimide (0·15 g.) collected (cf. Ziegler *et al.*, *Annalen*, 1942, **551**, 80). The filtrate was concentrated and then chromatographed on a column of alumina; two main bands formed. On development with benzene the faster orange-yellow band passed through the column, and evaporation of the eluate afforded small plates (0·35 g.), m. p. 211—215°. Recrystallisation from benzene–ligroin gave orange-yellow needles, m. p. 212—215° (Found: C, 60·3; H, 4·6; N, 3·6; Br, 22·0. $C_{18}H_{16}O_2NBr$ requires C, 60·3; H, 4·5; N, 3·9; Br, 22·35%). 2-*Amino*-1-*bromo*-3-tert.-*butylanthraquinone* forms yellow solutions in concentrated sulphuric acid and pyridine. A green colour develops when methyl-alcoholic potassium hydroxide is added to the pyridine solution. The quinone dissolves in alkaline sodium dithionite with a red colour.

The second band was reddish-orange; it yielded a small quantity of unchanged 2-amino-3-*tert*.-butylanthraquinone.

When bromine was added to a solution of 2-amino-3-*tert*.-butylanthraquinone in acetic acid yellow crystals separated. The product had m. p. 240—244°. It could not be obtained pure by recrystallisation; when its solution in acetic acid was added to water, 2-amino-3-*tert*.-butylanthraquinone was regenerated. The amine was also recovered mainly unaltered when it was heated at 160—170° in solution in nitrobenzene with an excess of bromine and much anhydrous sodium acetate.

Action of Fused Potassium Hydroxide on 2-*Amino*-3-tert.-*butylanthraquinone*. *Formation of* 3 : 3′-*Di*-tert.-*butylflavanthrone*.—2-Amino-3-*tert*.-butylanthraquinone (0·2 g.) was added to molten potassium hydroxide (5 g.) at 295—305°. After 20 minutes at this temperature the melt had become dark and a small amount of the amine had sublimed. The product was cooled, added to water (50 c.c.), and aerated for an hour. The yellowish-brown precipitate (0·12 g.) was collected, washed, dissolved in *o*-dichlorobenzene, and chromatographed on alumina. A strongly adsorbed brown zone formed, and a more mobile intensely yellow band. The latter passed through the column on development with benzene. The resulting eluate gave a product which crystallised from *o*-dichlorobenzene–methanol in small, brownish-yellow needles (Found: C, 82·9; H, 5·7; N, 5·1. $C_{36}H_{28}O_2N_2$ requires C, 83·1; H, 5·4; N, 5·4%). 3 : 3′-*Di*-tert.-*butylflavanthrone* is much more soluble in organic solvents than is flavanthrone; even in the cold, it dissolves in benzene, forming a solution which is distinctly yellow. In concentrated sulphuric acid it gives a bright orange solution. The yellow solution in hot pyridine becomes green on addition of methyl-alcoholic potassium hydroxide; excess of the reagent changes the colour to yellow and finally yields a precipitate. Flavanthrone behaves similarly, the yellow solution in pyridine becoming blue on addition of methyl-alcoholic potassium hydroxide; excess of the reagent gives a bluish-red precipitate. Like flavanthrone, 3 : 3′-di-*tert*.-butylflavanthrone gives a blue colour with cold 30—40% oleum, and on heating a red-violet. Scholl (*Ber.*, 1907, **40**, 1691) recorded that flavanthrone gave a red-violet colour with cold oleum, and on heating a blue. 3 : 3′-Di-*tert*.-butylflavanthrone dissolves in piperidine, forming a yellow solution; addition of hydrazine causes development of a blue colour and a red fluorescence. 3 : 3′-Di-*tert*.-butylflavanthrone dissolves in alkaline sodium dithionite, forming a blue solution; in reflected artificial light the solution exhibits a characteristic, intense violet colour; aeration re-forms the original orange-yellow colouring matter. The substance differs from flavanthrone in not being reduced by aqueous sodium sulphide.

When the potassium hydroxide fusion was carried out at 215—225° the product was more complex. Unchanged amine (15%) was recovered, the proportion of acidic compounds was higher than at 295—300°, and 3 : 3′-di-*tert*.-butylflavanthrone was isolated in appreciable amount, but there was no indication of the formation of a blue indanthrone derivative or the corresponding azine.

Self-condensation of 2-*Amino*-1-*bromo*-3-tert.-*butylanthraquinone*. *Formation of* 3 : 3′-*Di*-tert.-*butylflavanthrone, -indanthrone, and -indanthroneazine*.—(*a*) A solution containing 0·15 g. of 2-amino-1-bromo-3-*tert*.-butylanthraquinone in 5 c.c. of *o*-dichlorobenzene was heated under reflux for 24 hours with finely powdered sodium acetate (0·5 g.) and a trace of copper acetate. The solution, initially yellow, became green and then brown. The cooled suspension was filtered, and the residue washed in turn with benzene, alcohol, and water. The resulting dark powder (0·03 g.) had a yellowish-green lustre. It was chromatographed in chlorobenzene on alumina; two bands were formed. The lower, orange-yellow band consisted of 3 : 3′-di-*tert*.-butylflavanthrone, identical with the same compound prepared by the alkali fusion of 2-amino-3-*tert*.-butylanthraquinone. The more strongly adsorbed band was greenish-yellow, it consisted of 3 : 3′-di-*tert*.-butylindanthrone azine [see Experiment (*b*)].

The *o*-dichlorobenzene filtrate, passed through an alumina column, yielded a number of faint bands, and in addition an intense yellow band consisting of 3 : 3′-di-*tert*.-butylflavanthrone.

(*b*) In a similar experiment the heating was stopped after 6 hours; the suspension was then deep green. The undissolved material was collected and treated as in (*a*); it yielded 0·062 g. of a dark green microcrystalline powder. This product was chromatographed in chlorobenzene on alumina. Two main zones were formed, the upper zone blue and the lower zone yellow. Developed by means of benzene the blue zone separated into two closely similar bands. Elution of the yellow band yielded a dark, yellowish-green powder (0·022 g.) consisting of 3 : 3′-*di*-tert.-*butylindanthroneazine* (Found: C, 77·5; H, 5·4; N, 4·6. $C_{36}H_{28}O_4N_2$ requires C, 78·3; H, 5·1; N, 5·1). The azine dissolved in concentrated sulphuric acid with a red-brown colour. It gave the same colour in contact with 30—40% oleum. It dissolved in pyridine with a yellow colour, changed to green by addition of methyl-alcoholic potassium hydroxide. It dissolved with difficulty in alkaline sodium dithionite forming a blue solution; aeration gave a blue precipitate consisting of 3 : 3′-di-*tert*.-butylindanthrone (difference from 3 : 3′-di-*tert*.-butylflavanthrone).

Heated in air, the azine became green and then blue. When cooled at the point of melting, it yielded a dark product which exhibited a reddish metallic glance. This product dissolved in cold *o*-dichlorobenzene with a blue colour; in concentrated sulphuric acid the solution was red. The azine dissolved in

quinoline with a blue-green colour, in aniline with a green, and in piperidine with a greenish-blue colour, changed to blue on addition of hydrazine hydrate.

The two blue bands were eluted together by means of methanol–chlorobenzene. Evaporation yielded 0·013 g. of dark blue leaflets consisting of impure 3 : 3′-di-*tert.*-butylindanthrone (Found : C, 75·6; H, 5·4; N, 6·7%). These dissolved in cold benzene, forming a pale blue solution. The solution in chlorobenzene showed maximum absorption at 7250 Å; on exposure to light it became progressively greener. After several weeks the absorption spectrum had changed considerably, absorption had become very strong in the red region, the absorption maximum had moved to 6900 A., the intensity at the maximum had diminished, and absorption had become noticeable in the blue. In concentrated sulphuric acid there was maximum absorption at 4700 Å ($E = 148$); the absorption decreased and then increased again at longer wave-lengths, ε being 0·64 at 7000 Å. Addition of a drop of nitric acid to the solution in sulphuric acid changed the colour to yellow-brown immediately. The dihydroazine dissolved with difficulty in alkaline sodium dithionite, forming a blue solution. Aeration afforded a greenish-blue precipitate. As with many difficulty reducible quinones, the process of dissolving it in an alkaline reducing medium was facilitated by addition of pyridine (cf. Bradley and Sutcliffe, *J.*, in the press). It gave a greenish-olive colour with 30—40% oleum, changed (irreversibly) to red-brown on heating.

(*c*) In a third experiment the heating was stopped after 4 hours. The green solution was passed through a column of alumina whilst it was still warm, and without previous filtration. Development by chlorobenzene gave several bands; the most mobile was yellow, and this was succeeded by a bright red, a deep blue, and a deep brown zone. As development proceeded, increasing amounts of a yellow eluate were collected, whilst the remaining bands moved slowly down the column. It was then found that the yellow zone was being formed on the column from the blue. The yellow eluate afforded 0·043 g. of 3 : 3′-di-*tert.*-butylindanthroneazine. Exposure to light caused the yellow azine to become progressively greener.

The bright red band became bright yellow as soon as it was brought into contact with aqueous sodium hydroxide or exposed to air. For this reason the properties of the red compound could not be studied in detail. The yellow product was identified as 3 : 3′-di-*tert.*-butylflavanthrone; the yield was 0·01 g.

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