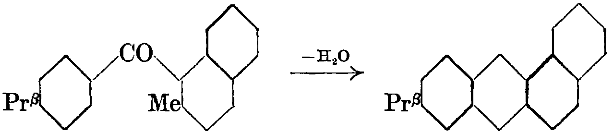
55. *Polycyclic Aromatic Hydrocarbons. Part IX. The Synthesis of Methyl and* iso*Propyl Homologues of* 1 : 2-*Benzanthracene.*

By JAMES WILFRED COOK.

WITH the exception of 3-methyl-1 : 2-benzanthracene (Cook, J., 1930, 1093) no true homologues of 1 : 2-benzanthracene have been isolated in the pure state, for it has been found that the 6-methyl compound has a melting point 24° higher than that of the substance so described by Dziewoński and Ritt (*Bull. Acad. Polonaise,* 1927, *A*, 181), while their 8-methyl compound was merely impure 1 : 2-benzanthracene.*

At the time when the experiments described in Part I of this series were performed, an attempt was made to prepare 6-*iso*propyl-1 : 2-benzanthracene (II) by pyrolysis of the ketone (I) formed from cuminoyl chloride and 2-methylnaphthalene :

(I.)



(II.)

---

* The I.G. Farbenind. A.-G. (D.R.-P. 481,819) have followed Dziewoński and Ritt in these errors, and some of the other data given in this specification are inaccurate.

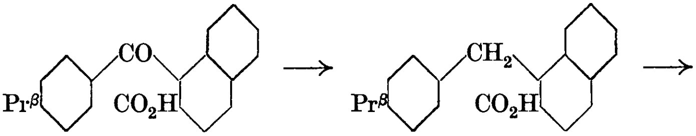
The product was a well-crystallised hydrocarbon, m. p. 114—115°. It was clear from the analytical figures that this substance was a mixture of an *iso*propylbenzanthracene with a compound of higher carbon content, and its heterogeneous nature was confirmed by a study of its picric acid additive compounds and of its chromic acid oxidation products.

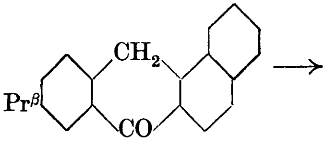
It was not found possible to separate the hydrocarbon mixture into its constituents, yet the observation made in this Institute by Professor E. L. Kennaway that the mixture, applied in 0·3% solution in benzene, produced 7 tumours (1 non-malignant, 2 doubtful, and 4 definite cancers) in a series of 10 mice during 13 months necessitated its further examination. Evidence was obtained that 6-methyl-1 : 2-benzanthracene was one constituent of the mixture, and this has been prepared in the pure state. It was subsequently observed that para-substituted derivatives of 1-benzoyl-2-methylnaphthalene could give rise, by pyrolytic migrations, to benzanthracenes substituted in position 7 as well as in position 6 (see p. 461). The problem was thus to obtain 6-*iso*propyl- and 7-*iso*propyl-1 : 2-benzanthracenes by non-pyrogenic methods, and this has been accomplished.

Naphthalene-1 : 2-dicarboxy anhydride condensed with cumene to give a mixture of 1-*cuminoyl*-2-*naphthoic acid* (III), m. p. 215—216°, and 2-*cuminoyl*-1-*naphthoic acid* (IV), m. p. 164—165°, the constitutions assigned being based on the fact that the former, on fusion with potassium hydroxide, yielded cuminic and 2-naphthoic acids, whereas the latter gave cuminic and 1-naphthoic acids. The two acids were further characterised by their *acetoxy-lactones* (V), formed by heating with pyridine and acetic anhydride at 100°. After these experiments were completed, Waldmann (*J. pr. Chem.*, 1931, **131**, 71; compare *ibid.*, 1930, **127**, 195) showed that benzene gives a similar mixture of benzoylnaphthoic acids when condensed with naphthalene-1 : 2-dicarboxy anhydride.

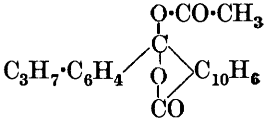
Various attempts to dehydrate the cuminoylnaphthoic acids to the benzanthraquinone derivatives failed; in any case, the possibility of intramolecular rearrangements of the type observed by Hayashi (J., 1930, 1513, 1520, 1524) would make it unwise to draw conclusions as to the structures of the quinones formed by the direct action of dehydrating agents. The cuminoylnaphthoic acids were therefore reduced by zinc dust and alkali prior to cyclisation. The reduced acids were contaminated with resinous by-products and could not be obtained crystalline; they were dehydrated in the crude state, by concentrated sulphuric acid at 0°, to anthrone-like substances which were then reduced to the hydrocarbons by fresh treatment with zinc dust and alkali :

(III.)





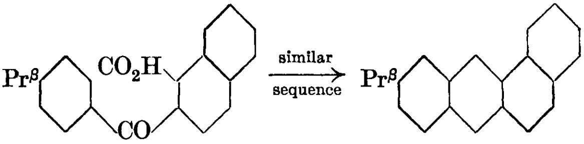
(II)



$$\mathrm{C_3H_7{\cdot}C_6H_4}\diagup\underset{\underset{\displaystyle\mathrm{CO}}{\overset{|}{\mathrm{O}}}}{\overset{\overset{\displaystyle\mathrm{O{\cdot}CO{\cdot}CH_3}}{|}}{\mathrm{C}}}\diagdown\mathrm{C_{10}H_6}$$

(V.)

(IV.)



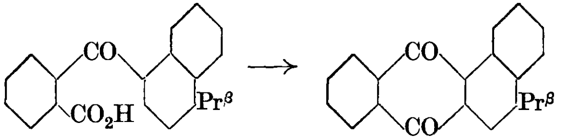
(VI.)

7-iso*Propyl*-1 : 2-*benzanthracene* (VI), thus obtained from 2-cuminoyl-1-naphthoic acid (IV), was characterised by its *picrate* and *quinone*. 6-iso*Propyl*-1 : 2-*benzanthracene* (II), obtained from 1-cuminoyl-2-naphthoic acid (III), was associated with a trace of an impurity; the impurity was converted by brief boiling with sodium dichromate in acetic acid into a very sparingly soluble product, readily separated from the easily soluble 6-iso*propyl*-1 : 2-*benzanthraquinone*. This highly crystalline quinone was reduced, by the two-stage method developed for 3-*iso*propyl-1 : 2-benzanthraquinone (see later), to pure 6-*iso*propyl-1 : 2-benzanthracene, m. p. 132—133°.

The presence of the last-named hydrocarbon in the mixture formed by pyrolysis of 1-cuminoyl-2-methylnaphthalene (I) was established by the isolation of 6-*iso*propyl-1 : 2-benzanthraquinone from the oxidation products of this mixture.

It seemed likely that the carcinogenic activity of the crude mixture containing 6-*iso*propyl-1 : 2-benzanthracene was due to this hydrocarbon, although a considerable time must elapse before this can be known with certainty. It was accordingly desirable to study isomeric hydrocarbons having the substituent in other positions, and to this end 3-iso*propyl*-1 : 2-*benzanthracene* and 10-iso*propyl*-1 : 2-*benzanthracene* were next prepared.

(VII.)



(VIII.)

3-*iso*Propyl-1 : 2-benzanthracene was obtained by a method analogous to that previously used for the 3-methyl compound; namely, reduction of 3-iso*propyl*-1 : 2-*benzanthraquinone* (VIII), formed by dehydration of the *acid* (VII) resulting from 1-*iso*propylnaphthalene and phthalic anhydride.

Reduction of the quinone with zinc dust and ammonia or potassium hydroxide solution proceeded beyond the benzanthraquinol stage only with the utmost difficulty (compare Cook, J., 1930, 1093; 1931, 3274), although a small yield of the *iso*propylbenzanthracene was isolated after 64 hours' heating. This difficulty was overcome by carrying out the reduction in two stages; the quinone was first reduced to the anthranol stage by stannous chloride in boiling acetic acid, and the crude product then further reduced by zinc dust and sodium hydroxide solution. Such a method should prove useful in other cases of anthraquinone derivatives which are resistant to alkaline reduction.

The position assigned to the *iso*propyl radical in this *iso*propylbenzanthracene is based on analogy, and attachment at position 1′ or 4′ (see formula on p. 460 for the system of numbering) of the benzanthracene ring system, although extremely improbable, is not finally excluded.

The 1-*iso*propylnaphthalene necessary for the above synthesis was prepared by reduction of 1-*iso*propenylnaphthalene, the product of dehydration of the carbinol resulting from ethyl 1-naphthoate and methylmagnesium iodide.*

The ethylenic compound was conveniently reduced by hydriodic acid in boiling acetic acid; a large proportion of the *iso*propenylnaphthalene was not reduced, but was converted into a saturated *dimeride*, m. p. 199°, which was also obtained by treatment of the *iso*propenyl compound with sulphuric acid in acetic acid solution. The dimeride is obviously identical with the substance mentioned by Schoepfle and Ryan (*J. Amer. Chem. Soc.*, 1930, **52**, 4023) as formed by the action of stannic chloride on dimethyl-α-naphthylchloromethane and in view of the work of these authors no attempt has been made to determine the structure.

10-*iso*Propyl-1 : 2-benzanthracene was obtained by the action of *iso*propylmagnesium bromide on 1 : 2-benz-10-anthrone, the hydrocarbon being isolated from the resin formed by dehydration of the crude dihydroanthranol, through the medium of its picrate.

At present, it may be said with certainty that 1 : 2 : 5 : 6-dibenzanthracene and 5 : 6-*cyclo*penteno-1 : 2-benzanthracene, which both contain 5 rings in the molecule, are cancer-producing compounds. If the pure 6-*iso*propyl-1 : 2-benzanthracene proves to be the

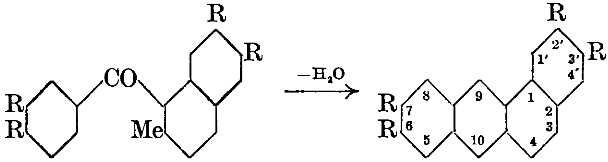
---

* After the conclusion of these experiments the synthesis of 1-*iso*propylnaphthalene by substantially the same method was reported by Herzenberg and Winterfeld (*Ber.*, 1931, **64**, 1043). The details of experimental procedure adopted by the present author seem simpler and more convenient, and are therefore recorded.

carcinogenic constituent of the original crude substance, this will be the simplest cancer-producing hydrocarbon yet examined. Now, 1 : 2-benzanthracene itself has, so far, given only negative results, and it is thus desirable to ascertain at what precise degree of molecular complexity the property begins to manifest itself. A number of methyl derivatives of 1 : 2-benzanthracene have therefore been prepared, and the synthesis of ethyl compounds is in progress.

For the time being, attention has been confined to the methyl compounds substituted only in β-positions in the benzanthracene ring system, which were thus obtainable by the Elbs method of pyrolysis of suitable ketones. For it has already been shown in the anthracene and 1 : 2 : 5 : 6-dibenzanthracene series that methyl groups in an α-position are eliminated under the conditions necessary to effect the Elbs reaction (Cook, J., 1930, 1088; 1931, 490), and the observation that the 8-methyl-1 : 2-benzanthracene of Dziewoński and Ritt (*loc. cit.*) is really 1 : 2-benzanthracene has shown that the same generalisation holds for the benzanthracene series.

All of the four possible β-monomethyl-1 : 2-benzanthracenes were prepared by pyrolysis of the appropriate dimethyl derivatives of 1-benzoylnaphthalene, and five of the six possible β-dimethyl-1 : 2-benzanthracenes were obtained from the corresponding trimethyl-1-benzoylnaphthalenes :

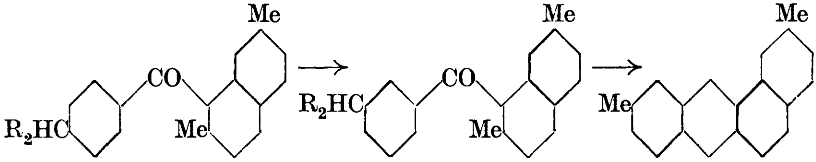


(R = H or Me)

Intramolecular rearrangements occurred, in some cases to considerable extents, so that the crude hydrocarbons had melting points very much below those of the pure substances. With the *m*-tolyl ketones there was the added possibility of ring closure taking place at two positions in the benzene ring, although direct proof of condensation ortho to methyl was not obtained. Crystallisation alone was of little avail for the isolation of the pure hydrocarbons; this was achieved, however, by purification through the picrates, and in every case the homogeneous nature of the sharp-melting pure hydrocarbon was confirmed by oxidation to the well-crystallised quinone. Certain of the quinones are being utilised in experiments which have as their object the production of benzanthracene derivatives containing more complex aliphatic and ethylenic side chains.

Dziewoński and Ritt (*loc. cit.*) isolated 2 : 3-benzanthracene as a by-product of the pyrolytic dehydrogenation of 1-benzyl-2-methylnaphthalene to 1 : 2-benzanthracene. They attributed this to partial migration of the benzyl group from position 1 to position 3 in the naphthalene nucleus, but isolated only 1 : 2-benzanthracene by pyrolytic dehydration of 1-benzoyl-2-methylnaphthalene. Nevertheless, the deep yellow colour of their 1 : 2-benzanthracene, which is colourless when pure, suggested contamination with the orange 2 : 3-benzanthracene, so that migration of the benzoyl group had probably taken place to some slight extent. No coloured derivatives of 2 : 3-benzanthracene were isolated from the crude mono- and di-methyl-1 : 2-benzanthracenes, so that the migration of the acyl group of 1-acyl-2-methylnaphthalene derivatives from position 1 to position 3 is a change which occurs only to a very minor extent.

On the other hand, the migration of the substituted naphthoyl radical was established by the isolation of 2′ : 7-*dimethyl*-1 : 2-*benzanthracene* (XI) as a by-product of the pyrolysis of 1-p-*toluoyl*-2 : 7-*dimethylnaphthalene* (IX ; R = H). This hydrocarbon was the chief product of pyrolysis of 1-m-*toluoyl*-2 : 7-*dimethylnaphthalene* (X ; R = H), and the change by which it is formed from the former ketone is analogous to the migrations already observed among the more complex 1 : 1′-dinaphthyl ketone derivatives (Cook, J., 1931, 488, 489) :



(IX.) (X.) (XI.)

(R = H or Me)

2′ : 7-Dimethyl-1 : 2-benzanthracene (XI) was also isolated from the products of pyrolysis of 1-cuminoyl-2-methylnaphthalene (IX ; R = Me), the migration in this case being accompanied by degradation of the *iso*propyl group to a methyl group. Other examples of the degradation of alkyl groups by pyrolysis are cited by H. Meyer (*Z. angew. Chem.*, 1924, **37**, 796).

The crude hydrocarbons resulting from the pyrolysis of *benzoyl*-2 : 6 - *dimethylnaphthalene* and *benzoyl* - 2 : 7 - *dimethylnaphthalene*, where the production of isomerides by naphthoyl migration was not possible, were comparatively pure, a result which indicated that there was very little tendency for β-methyl groups in the naphthalene ring system to migrate or to become eliminated.

With the possibility of migrations of the type discussed above, it is out of the question, in any single instance, to conclude that the hydrocarbon isolated from the crude pyrolysis product has a structure corresponding to that of the original ketone. Nevertheless, the orientation of each of the nine methyl and dimethyl benzanthracenes may be deduced from the structure of its antecedent ketone, for all nine were different from one another, and this deduction depends only on the assumption, for which there is ample justification, that α-methyl groups could not survive the pyrolytic treatment.

EXPERIMENTAL.

6- *and* 7-iso*Propyl*-1 : 2-*benzanthracenes*.

Cuminoylnaphthoic Acids.—1 : 2-Dicyanonaphthalene was obtained by distillation of a mixture of sodium 1-chloronaphthalene-2-sulphonate and potassium ferrocyanide in carbon dioxide (Cleve, *Ber.*, 1892, **25**, 2475; compare Waldmann, *J. pr. Chem.*, 1930, **127**, 197): the yield was far short of the 50% claimed by Waldmann. The dinitrile was heated under reflux with 30% methyl-alcoholic potassium hydroxide for an hour, the crystals which separated were dissolved by addition of water, and the precipitate formed on acidification, which was an intermediate nitrogenous compound, was hydrolysed to naphthalene-1 : 2-dicarboxylic acid by boiling 50% aqueous potassium hydroxide solution in 1½ hours. The acid, formed in good yield, was sublimed in a vacuum at 180—200°, and the anhydride recrystallised from xylene.

A suspension of naphthalene-1 : 2-dicarboxy anhydride (36 g.) in cumene (120 c.c.) was treated gradually, with agitation, with powdered anhydrous aluminium chloride (54 g.). The deep red liquid was kept at room temperature, with occasional shaking, for 6½ hours and then decomposed with ice and hydrochloric acid and steam-volatile substances were removed. The viscid residue was extracted with boiling dilute sodium hydroxide solution, and the cooled solution filtered from resinous matter and acidified. The precipitate was extracted with dilute sodium carbonate solution, and the acid reprecipitated from the filtered solution. The crude mixture of acids was dried in a vacuum desiccator (yield, 43 g.). This was twice recrystallised from benzene and then formed colourless needles (13·5 g.), m. p. 164—165°, soluble in concentrated sulphuric acid with a dark reddish-brown colour (Found: C, 79·2; H, 5·6. $C_{21}H_{18}O_3$ requires C, 79·25; H, 5·7%).

The constitution of this isomeride as 2-*cuminoyl*-1-*naphthoic acid* (IV) was shown by fusion with alkali. The acid (0·7 g.) was gradually stirred into molten potassium hydroxide (5 g.) at 260°. After 10 minutes at 260—280°, the melt was cooled and extracted with water. The precipitate formed on acidification was collected, dried, and twice recrystallised from benzene; it then melted at 160—161°, alone or mixed with 1-naphthoic acid. The benzene liquors were evaporated to dryness and the residue was recrystallised from *cyclo*hexane. The crystals were a mixture; the liquors were evaporated to dryness, and yielded cuminic acid, which had m. p. 116—117°, alone or mixed with an authentic sample, after recrystallisation from aqueous alcohol.

The *acetoxy-lactone* (V) of 2-cuminoyl-1-naphthoic acid (IV) was formed by heating a solution of the acid (1 g.) in pyridine (5 c.c.) and acetic anhydride (1·5 c.c.) at 100° for 2 hours. The solution was cooled and diluted with water; an oil separated which afterwards solidified. After two recrystallisations from alcohol this formed colourless leaflets, m. p. 126—127° (Found: C, 76·5; H, 5·7. $C_{23}H_{20}O_4$ requires C, 76·7; H, 5·55%).

The benzene liquors from 2-cuminoyl-1-naphthoic acid were evaporated to small bulk. On standing, the solution slowly crystallised; the solid was separated from the thick syrupy liquid and recrystallised from aqueous acetic acid. It was possible to obtain the 1-*cuminoyl*-2-*naphthoic acid* (III) in a pure state by repeated crystallisation from aqueous acetic acid, but it was found better to purify the substance through the *acetoxy-lactone* (V), prepared in the same way as the isomeride. It separated from alcohol in colourless needles, m. p. 158—159° (Found: C, 76·8; H, 5·4. $C_{23}H_{20}O_4$ requires C, 76·7; H, 5·55%). This acetoxy-lactone was hydrolysed by boiling alcoholic potassium hydroxide solution, and the resulting 1-*cuminoyl*-2-*naphthoic acid* (III) crystallised from aqueous acetic acid. It formed small, colourless needles (5·8 g.), m. p. 215—216°, giving a dark green solution in concentrated sulphuric acid (Found: C, 79·0; H, 5·8. $C_{21}H_{18}O_3$ requires C, 79·25; H, 5·7%).

When this acid (III) was subjected to alkaline fusion under the same conditions as 2-cuminoyl-1-naphthoic acid (IV) it was largely recovered unchanged. Fission was effected as follows: 1-Cuminoyl-2-naphthoic acid (0·5 g.) was stirred into a mixture of potassium hydroxide (4 g.) and water (0·5 c.c.) at 280°. The fused mass was kept at 300° for ½ hour and then worked up exactly as described for the isomeride. It yielded 2-naphthoic and cuminic acids.

6-iso*Propyl*-1 : 2-*benzanthracene* (II).—A solution of 1-cuminoyl-2-naphthoic acid, m. p. 215—216° (3·2 g.), in *N*-potassium hydroxide solution (160 c.c.) was boiled for 24 hours with zinc dust (8 g.). The use of more concentrated alkali was not desirable, as it caused separation of the liquid hydrated salt; if ammonia was used, the reduction ceased at the lactone stage. The cold solution, filtered from zinc, was acidified, and the precipitate extracted with dilute sodium carbonate solution. The acid was reprecipitated from the filtered cold solution, and dried in a vacuum desiccator (yield, 2·8 g.). The reduced acid gave an orange fluorescent solution in concentrated sulphuric acid. It was contaminated with resinous by-products, possibly formed by partial reduction of the naphthalene ring system, and could not be obtained crystalline.

For dehydration to the anthrone, the crude reduced acid was added gradually to ice-cold concentrated sulphuric acid (60 c.c.). After 2½ hours at 0°, the solution was poured on ice, and the precipitate collected and immediately reduced by boiling its suspension in *N*-sodium hydroxide with zinc dust for 3 hours. The mixture of hydrocarbon and excess zinc was collected (acidic by-products remained in solution), the zinc removed by digestion with hydrochloric acid, and the crude hydrocarbon dried (yield, 1·05 g.).

This hydrocarbon was purified through its red picrate, m. p. 118° after sintering, which did not crystallise well. It was decomposed with sodium carbonate solution, and the hydrocarbon recrystallised from alcohol; it then formed a colourless crystalline powder, m. p. 131—132°, after sintering at 129—130° (Found : C, 93·0; H, 6·6. $C_{21}H_{18}$ requires C, 93·3; H, 6·7%). 6-iso*Propyl*-1 : 2-*benzanthracene* (II), in common with other benzanthracene hydrocarbons, gave a carmine-red fluorescent solution in concentrated sulphuric acid, the colour becoming purple and finally blue on standing or gentle warming.

6-iso*Propyl*-1 : 2-*benzanthraquinone*.—A solution of the aforesaid hydrocarbon (0·4 g.) in glacial acetic acid (10 c.c.) was treated with sodium dichromate (0·8 g.). After 10 minutes' boiling, the solution was cooled and diluted with water. The oil which separated was washed by decantation and extracted with boiling alcohol. There remained undissolved 0·01 g. of a very sparingly soluble, yellow powder, m. p. 300—315°, after darkening, which was not further examined. The alcoholic filtrate gave orange-yellow needles of 6-iso*propyl*-1 : 2-*benzanthraquinone* which, after recrystallisation from alcohol, had m. p. 94—95° (Found : C, 84·0; H, 5·5. $C_{21}H_{16}O_2$ requires C, 84·0; H, 5·3%).

This pure quinone was reduced, first with stannous chloride in acetic acid, and then with zinc dust and alkali just as later described in the case of 3-*iso*propyl-1 : 2-benzanthraquinone. The resulting pure 6-*iso*propyl-1 : 2-benzanthracene (II) separated from alcohol in tufts of colourless needles, m. p. 132—133° without previous sintering.

7-iso*Propyl*-1 : 2-*benzanthracene* (VI).—This was obtained from 2-cuminoyl-1-naphthoic acid, m. p. 164—165°, in the same way as the isomeride. The crude reduction product (4·6 g. from 6 g. of the keto-acid) was dehydrated at 0° in 2 hours with concentrated sulphuric acid (60 c.c.) and the product reduced by zinc dust and boiling *N*-sodium hydroxide solution for 3 hours. The crude hydrocarbon (1·4 g.) was almost pure, and after two recrystallisations from alcohol formed colourless leaflets, m. p. 125° (Found : C, 93·0; H, 6·8. $C_{21}H_{18}$ requires C, 93·3; H, 6·7%).

The *picrate* of 7-*iso*propyl-1 : 2-benzanthracene, formed in alcoholic solution, recrystallised from 5% alcoholic picric acid, and washed with alcohol, consisted of dark red needles, m. p. 152° (Found : C, 65·1; H, 4·9. $C_{21}H_{18},C_6H_3O_7N_3$ requires C, 65·1; H, 4·2%).

7-iso*Propyl*-1 : 2-*benzanthraquinone*, formed by oxidation of the hydrocarbon (1 part) with sodium dichromate (2 parts) in boiling acetic acid for 10 minutes, separated from alcohol in long golden-yellow needles, m. p. 114—115° (Found : C, 83·8; H, 5·3. $C_{21}H_{16}O_2$ requires C, 84·0; H, 5·3%).

Pyrolysis of 1-*Cuminoyl*-2-*methylnaphthalene* (I).—The ketone, prepared from cuminoyl chloride (21 g.), 2-methylnaphthalene (18 g.), and anhydrous aluminium chloride (30 g.) in carbon disulphide (100 c.c.), formed an amber syrup, b. p. 262°/12 mm., which could not be obtained crystalline. It was heated at 410—420° for 2 hours, and the residue distilled in a vacuum. The distillate, b. p. 220—280°/5 mm., was dissolved in *cyclo*hexane, and the crystalline product recrystallised from alcohol. It formed pale yellow leaflets, m. p. 114—115°, from which the colour could be removed by agitation with sulphuric acid in benzene solution (Found : C, 93·9; H, 6·0. Calc. for $C_{21}H_{18}$: C, 93·3; H, 6·7%). The yield was 3 g. from 50 g. of cuminoyl chloride. This mixture could not be separated by crystallisation. It gave a dark red picrate, m. p. 116·5—117°. By repeated crystallisation the m. p. was brought to 128—132°, depressed by 1 : 2-benzanthracene picrate, but not by 6-methyl-1 : 2-benzanthracene picrate. The m. p. of the hydrocarbon mixture was depressed by 7-*iso*propyl-1 : 2-benzanthracene (VI) but not by 6-*iso*propyl-1 : 2-benzanthracene (II). Oxidation with sodium dichromate in acetic acid gave an oil which, by crystallisation from alcohol, yielded a rather sparingly soluble substance which seemed to consist of impure 6-methyl-1 : 2-benzanthraquinone. The more soluble fractions yielded orange needles, m. p. 87—90°, shown by the method of mixed melting points to be almost pure 6-*iso*propyl-1 : 2-benzanthraquinone.

3-iso*Propyl*-1 : 2-*benzanthracene*.

1-iso*Propenylnaphthalene*.—An ice-cold solution of methylmagnesium iodide (2 mols.) was treated with ethyl 1-naphthoate (1 mol.), the whole allowed to warm to room temperature, and finally boiled for an hour. The product was decomposed with ice and ammonium chloride, and the dimethyl-1-naphthyl carbinol remaining after removal of the ether washed with light petroleum (compare Kay and Morton, J., 1914, **105**, 1581). For dehydration to the ethylenic compound, a solution of the carbinol (85 g.) in alcohol (350 c.c.) and concentrated hydrochloric acid (15 c.c.) was boiled for an hour. The solution was poured into water, extracted with ether, and the washed ethereal solution distilled. The resulting 1-*iso*propenylnaphthalene (70 g.), b. p. 123—125°/10—11 mm., gave a picrate, m. p. 88—90° (Grignard, *Bull. Soc. chim.*, 1901, **25**, 498, gives 91°, although Kay and Morton, *loc. cit.*, give 141°).

1-iso*Propylnaphthalene.*—It was observed that alcohol and sufficient sodium completely to reduce the ethylenic hydrocarbon (detected by its blood-red colour with concentrated sulphuric acid) gave an oil which formed no picrate. This accords with the experiments of Herzenberg and Winterfeld (*Ber.*, 1931, **64**, 1043). A solution of 1-*iso*propenylnaphthalene (35 g.) in acetic acid (420 c.c.) was therefore reduced by boiling for ¾ hour with hydriodic acid (*d* 1·9; 35 c.c.), and then poured into sodium bisulphite solution to destroy the liberated iodine. The product was shaken with ether, and the ethereal suspension filtered. The white solid product (8·5 g.), sparingly soluble in ether, crystallised from *cyclo*hexane–alcohol in colourless crystals, m. p. 198·5—199·5° (Found: C, 92·7; H, 7·2. M, cryoscopic in ethylene dibromide, 313. $C_{26}H_{24}$ requires C, 92·8; H, 7·2%; M, 332). This *dimeride* of 1-*iso*propenylnaphthalene, which did not decolorise a solution of bromine in carbon disulphide, was also formed by boiling the ethylenic hydrocarbon in acetic acid containing sulphuric acid.

The ethereal solution from the above reduction was evaporated on the water-bath, and the residual oil added to ice-cold sulphuric acid to polymerise a small amount of ethylenic compound which had survived the hydriodic acid treatment. The mixture was poured into water, again extracted with ether, and the oil distilled (a further 2 g. of the dimeride were isolated). 1-iso*Propylnaphthalene*, after redistillation over sodium, had b. p. 132°/12 mm. and 263—264°/769 mm. (yield, 16 g.) (Found: C, 91·4; H, 8·2. $C_{13}H_{14}$ requires C, 91·7; H, 8·3%).

The *picrate* of 1-*iso*propylnaphthalene, prepared in alcoholic solution and recrystallised from alcohol, formed yellow needles, m. p. 83·5—86°, depressed by 1-*iso*propenylnaphthalene picrate, and also by the picrate, m. p. 91—93°, of the 2-*iso*propylnaphthalene, b. p. 263—265°, prepared by the action of *iso*propyl bromide on naphthalene in presence of catalytic amounts of aluminium chloride (compare Roux, *Bull. Soc. chim.*, 1884, **41**, 379; *Ann. Chim. Phys.*, 1887, **12**, 313) (Found: C, 57·3; H, 4·75. $C_{13}H_{14},C_6H_3O_7N_3$ requires C, 57·1; H, 4·3%).

It was found unnecessary to isolate the *iso*propenyl compound in the above preparation. Direct reduction of dimethyl-1-naphthylcarbinol (82 g.) with hydriodic acid in acetic acid yielded 33 g. of pure 1-*iso*propylnaphthalene, together with a corresponding amount of the dimeride of 1-*iso*propenylnaphthalene.

The chief disadvantage of the above method lies in the large proportion of material converted into the dimeric by-product. The method of Herzenberg and Winterfeld (*loc. cit.*) is by no means ideal. An attempt was therefore made to simplify the reduction by using a catalytic hydrogenation method. 1-*iso*Propenylnaphthalene (1 part), diluted with *iso*propyl alcohol (5 parts), was hydrogenated at 115—120° under a pressure of 50 lb. per sq. in. with a nickel catalyst. The product, which contained unchanged *iso*propenyl compound, formed a picrate which, after one recrystallisation from alcohol, gave pure 1-*iso*propylnaphthalene picrate. At higher temperatures and pressures ring-hydrogenation occurred. For example, at 145—150° and under a pressure of 150 lb. per sq. in. there was formed a product, free from *iso*propenyl compound, which gave no picrate, and which gave carbon and hydrogen figures between those required for dihydro- and tetrahydro-*iso*propylnaphthalenes. The pure *iso*propylnaphthalene was obtained from this mixture by dehydrogenation with sulphur at 200—220°, followed by distillation over sodium.

Condensation of 1-iso*Propylnaphthalene with Phthalic Anhydride.*—Powdered anhydrous aluminium chloride (40 g.) was added gradually to a suspension of phthalic anhydride (20 g.) in 1-*iso*propylnaphthalene (34 g.) diluted with benzene (60 c.c.). The resulting dark red syrup was kept for 7 hours at room temperature with occasional shaking. Steam-volatile products were removed (naphthalene was isolated at one stage of the steam distillation), and the residue extracted with boiling dilute sodium carbonate solution. The crude acid, obtained by acidification, was dried in a vacuum desiccator (yield, 46 g.) and twice recrystallised from aqueous acetic acid. The acid was then pure (8·5 g.), a sample for analysis being recrystallised from benzene (Found: C, 79·2; H, 5·7. $C_{21}H_{18}O_3$ requires C, 79·25; H, 5·7%). 4′-iso*Propyl*-1′-*naphthoyl*-2-*benzoic acid* (VII) formed a colourless crystalline powder, m. p. 206—208°.

3-iso*Propyl*-1 : 2-*benzanthraquinone* (VIII).—The purple solution of the foregoing phthaloylic acid (3 g.) in concentrated sulphuric acid (45 c.c.) was heated at 60° for 2½ hours, cooled, and poured into water. The precipitate was collected, extracted with boiling dilute sodium hydroxide solution, and the insoluble residue recrystallised from aqueous acetic acid. The *quinone* (1·1 g.), recrystallised from *cyclo*hexane (animal charcoal), formed lemon-yellow silky needles, m. p. 154—155° (Found : C, 83·8; H, 5·4. $C_{21}H_{16}O_2$ requires C, 84·0; H, 5·3%). The small yield was due to loss by sulphonation.

3-iso*Propyl*-1 : 2-*benzanthracene*.—To a solution of the quinone (VIII; 2·5 g.) in boiling glacial acetic acid (100 c.c.) was added a solution of stannous chloride (10 g.) in concentrated hydrochloric acid (20 c.c.). After boiling for an hour, the solution was cooled and diluted with water, and the precipitate collected and washed; it was free from quinone and gave an anthranol-yellow solution in boiling aqueous alkali. The substance was further reduced by boiling its suspension in 2*N*-sodium hydroxide solution (50 c.c.) with zinc dust (7 g.) for 3 hours. The liquid was filtered, the unused zinc removed by digestion with hydrochloric acid, the undissolved resinous mass dissolved in acetic acid, and the solution treated with picric acid (3·5 g.). 3-iso*Propyl*-1 : 2-*benzanthracene picrate* separated in dark red needles (2·75 g.), m. p. 157° after recrystallisation from benzene (Found : C, 64·9; H, 4·5. $C_{21}H_{18},C_6H_3O_7N_3$ requires C, 65·1; H, 4·2%). The picrate was decomposed in ethereal solution with sodium carbonate solution; the resulting 3-iso*propyl*-1 : 2-*benzanthracene* crystallised from a little glacial acetic acid as a colourless crystalline powder, m. p. 92° (Found : C, 93·0; H, 6·8. $C_{21}H_{18}$ requires C, 93·3; H, 6·7%).

10-iso*Propyl*-1 : 2-*benzanthracene*.

A Grignard solution prepared from magnesium turnings (5 g.), *iso*propyl chloride (19 c.c.), and anhydrous ether (150 c.c.) was cooled in ice and treated gradually with crude powdered 1 : 2-benz-10-anthrone (Cook, J., 1930, 1093) (17 g.). The mixture was kept in ice for 3½ hours and then at room temperature for an hour, the product decomposed with ice and ammonium chloride, the ethereal solution washed and dried over anhydrous sodium sulphate, and the ether removed. The residual viscous amber oil could not be induced to crystallise, so the crude *iso*propyldihydrobenzanthranol was dehydrated by warming its solution in glacial acetic acid (75 c.c.) and hydrochloric acid (2 c.c.). The resulting hydrocarbon was obtained free from resinous by-products by the addition of a solution of picric acid (20 g.) in acetic acid (75 c.c.). This resulted in separation of a thick meal of light reddish-brown needles, which were recrystallised from 5% alcoholic picric acid. This picrate (m. p. 157—158°) was decomposed with ammonia. The resulting 10-iso*propyl*-1 : 2-*benzanthracene* separated slowly from its supersaturated cold solution in acetic acid as large colourless crystals, m. p. 94—95° (Found : C, 93·3; H, 6·7. $C_{21}H_{18}$ requires C, 93·3; H, 6·7%).

Methyl Derivatives of 1 : 2-*Benzanthracene.*

Preparation of the Ketones.—A mixture of the appropriate acid chloride (1 part) with the suitable methyl- or dimethyl-naphthalene (1 part) and carbon disulphide (3 parts) was treated at 0° with anhydrous aluminium chloride (1 part), and kept at 0° for 6 hours. The product was decomposed with ice and hydrochloric acid, and steam-volatile substances were removed, the steam distillation being completed in presence of alkali, to destroy any excess of acid chloride. The residual ketones were then crystallised, first from acetic acid and then from methyl alcohol (animal charcoal), until they melted constantly. They were all well-crystallised colourless compounds, formed in good yield, and gave orange-red solutions in concentrated sulphuric acid. The acid chlorides and hydrocarbons employed are apparent from the names :

1-*m*-Toluoyl-2-methylnaphthalene, m. p. 107·5—108·5° (Mayer, Fleckenstein, and Günther, *Ber.*, 1930, **63**, 1471, give m. p. 104—105°).

1-(3′ : 4′-*Dimethylbenzoyl*)-2-*methylnaphthalene* (from 2 methylnaphthalene and 3 : 4-dimethylbenzoyl chloride; Morgan and Coulson, J., 1931, 2326), m. p. 109° (Found : C, 87·4; H, 6·55. $C_{20}H_{18}O$ requires C, 87·6; H, 6·6%).

1-*Benzoyl*-2 : 6-*dimethylnaphthalene*, m. p. 84° (Found : C, 88·0; H, 6·2. $C_{19}H_{16}O$ requires C, 87·7; H, 6·15%).

1-*Benzoyl*-2 : 7-*dimethylnaphthalene*, m. p. 91—92° (Found : C, 87·6; H, 6·0%).

1-m-*Toluoyl*-2 : 6-*dimethylnaphthalene*, m. p. 82° (Found : C, 87·4; H, 6·7. $C_{20}H_{18}O$ requires C, 87·6; H, 6·6%).

1-m-*Toluoyl*-2 : 7-*dimethylnaphthalene*, m. p. 115—116° (Found : C, 87·4; H, 6·7%).

1-p-*Toluoyl*-2 : 6-*dimethylnaphthalene*, m. p. 109° (Found : C, 87·3; H, 6·65%).

1-p-*Toluoyl*-2 : 7-*dimethylnaphthalene*, m. p. 98—99° (Found : C, 87·4; H, 6·5%).

Pyrolysis of the Ketones.—The ketones were dehydrated by heating in a Claisen flask of Pyrex glass, in a metal-bath, until water was no longer formed and boiling had ceased. In most cases this took about 2 hours at 440—450° or 4 hours at 410—420°, although in some cases a longer time was necessary. It was not found that the longer heating at the lower temperature gave purer products than the shorter heating at the higher temperature. The residue in the flask was then distilled, the fraction, b. p. 210—280°/5—7 mm., being recrystallised from acetic acid; very little advantage accrued from fractional distillation at this stage.

For purification of the crude hydrocarbons, the substance obtained in this way (1 part) was converted into picrate by crystallisation from acetic acid containing picric acid (1·5 parts). The dark red crude picrate was dried and recrystallised from benzene until it had a constant melting point. 2′ : 7-Dimethyl-1 : 2-benzanthracene did not form a picrate; the hydrocarbon itself crystallised from the acetic acid–picric acid mixture. In three other cases (7-methyl-, 3′ : 6-dimethyl-, and 3′ : 7-dimethyl-benzanthracenes) the picrates first formed were partly or wholly decomposed by recrystallisation from benzene. In spite of this, the same general procedure was adopted, as the picrates of by-products remained in solution. This dissociation of the picrates appeared to be due to the fact that in these particular cases the hydrocarbons were less soluble than the picrates rather than to any depressed capacity to form picrates.

In the other cases the picrates, which crystallised in dark red needles, were decomposed in benzene solution by shaking with sodium carbonate solution, and the benzene solution was then shaken with a little concentrated sulphuric acid to remove traces of coloured impurities. The final pure hydrocarbons separated from suitable solvents as colourless leaflets of sharp melting point.

The yields of crude hydrocarbons were about 20—25%, and of pure hydrocarbons, about 5—10%, calculated with reference to the ketones, although the yield of pure 3′ : 7-dimethyl-1 : 2-benzanthracene was only about 1%.

For oxidation to the quinones, a solution (or suspension) of the pure hydrocarbon (1 part) in glacial acetic acid (25 parts) was boiled for an hour with sodium dichromate (2 parts). The quinones, which crystallised on cooling, were fairly pure, but were recrystallised to constant melting point before analysis. They were all obtained in orange needles, of various shades.

1 : 2-*Benzanthracene*.—The crude hydrocarbon, m. p. 147—150°, formed by pyrolysis of 1-*o*-toluoyl-2-methylnaphthalene, was purified through the picrate and then melted at 158—159° alone or mixed with authentic 1 : 2-benzanthracene. The product of this reaction was described as 8-methyl-1 : 2-benzanthracene by Dziewoński and Ritt (*loc. cit.*).

6-*Methyl*-1 : 2-*benzanthracene*, from 1-*p*-toluoyl-2-methylnaphthalene; m. p. 150·5—151·5°, from alcohol (compare Dziewoński and Ritt, *loc. cit.*) (Found : C, 94·1; H, 5·9. $C_{19}H_{14}$ requires C, 94·2; H, 5·8%); *picrate*, m. p. 152—153° (Found : C, 63·6; H, 3·8. $C_{19}H_{14},C_6H_3O_7N_3$ requires C, 63·7; H, 3·6%); the quinone melted at 174°, in agreement with Dziewoński and Ritt.

7-*Methyl*-1 : 2-*benzanthracene*, from 1-*m*-toluoyl-2-methylnaphthalene; m. p. 182°, from benzene (Found : C, 94·1; H, 5·9%); *quinone*, m. p. 167°, from acetic acid (Found : C, 83·6; H, 4·5. $C_{19}H_{12}O_2$ requires C, 83·8; H, 4·4%).

2′-*Methyl*-1 : 2-*benzanthracene*, from 1-benzoyl-2 : 7-dimethylnaphthalene; m. p. 149—150°, from alcohol (Found: C, 93·9; H, 5·8%); *picrate*, m. p. 180° (Found : C, 64·0; H, 4·2%); *quinone*, m. p. 189—190°, from methyl ethyl ketone (Found : C, 83·7; H, 4·5%).

3′-*Methyl*-1 : 2-*benzanthracene*, from 1-benzoyl-2 : 6-dimethylnaphthalene; m. p. 160° (depressed by 1 : 2-benzanthracene), from alcohol (Found : C, 93·9; H, 5·8%); *picrate*, m. p. 144—145° (Found : C, 63·6; H, 4·0%); *quinone*, m. p. 168°, from methyl ethyl ketone (Found : C, 83·75; H, 4·5%).

6 : 7-*Dimethyl*-1 : 2-*benzanthracene*, from 1-(3′ : 4′-dimethylbenzoyl)-2-methylnaphthalene; m. p. 174°, from ethyl acetate (Found : C, 93·95; H, 6·4. $C_{20}H_{16}$ requires C, 93·7; H, 6·3%); *picrate*, m. p. 170° (Found : C, 64·3; H, 4·4. $C_{20}H_{16},C_6H_3O_7N_3$ requires C, 64·3; H, 3·9%); *quinone*, m. p. 193°, from benzene (Found : C, 83·6; H, 5·1. $C_{20}H_{14}O_2$ requires C, 83·9; H, 4·9%).

2′ : 6-*Dimethyl*-1 : 2-*benzanthracene*, from 1-*p*-toluoyl-2 : 7-dimethylnaphthalene; m. p. 164°, from acetic acid (Found : C, 93·7; H, 6·3%); *picrate*, m. p. 199—200° (Found : C, 64·1; H, 4·4%); *quinone*, m. p. 160—161°, from benzene (Found : C, 83·9; H, 4·9%).

2′ : 7-*Dimethyl*-1 : 2-*benzanthracene* (XI).—(i) From 1-*m*-toluoyl-2 : 7-dimethylnaphthalene; m. p. 236°, from xylene (Found : C, 93·6; H, 6·3%); *quinone*, m. p. 176·5—177·5°, from benzene (Found : C, 84·0; H, 5·0%).

(ii) The same hydrocarbon was also obtained by repeated crystallisation from benzene of the hydrocarbons recovered from the benzene picrate liquors of the crude product of pyrolysis of 1-*p*-toluoyl-2 : 7-dimethylnaphthalene. It was identified by direct comparison with a sample prepared as described under (i) and also by conversion into the quinone.

(iii) The brittle resinous ketone (IX; R = Me), b. p. 225°/4 mm., obtained from cuminoyl chloride and 2 : 7-dimethylnaphthalene, was submitted to pyrolysis in the usual way. The only pure compound isolated from the small yield of solid hydrocarbons was 2′ : 7-dimethyl-1 : 2-benzanthracene, identified by the method of mixed melting points.

3′ : 6-*Dimethyl*-1 : 2-*benzanthracene*, from 1-*p*-toluoyl-2 : 6-dimethylnaphthalene; m. p. 186—187°, from ethyl acetate (Found : C, 93·5; H, 6·3%); *quinone*, m. p. 205—205·5°, from ethyl acetate (Found : C, 83·9; H, 4·95%).

In one experiment the crude hydrocarbon, which had been exposed to the air for several days, was purified in the usual manner, and the purified hydrocarbon was found to be contaminated with a product very sparingly soluble in benzene. This was twice recrystallised from xylene, and formed almost colourless needles, m. p. 250—263° (decomp.), which had the properties of a dianthrone (Found : C, 88·3; H, 5·6. $C_{40}H_{30}O_2$ requires C, 88·5; H, 5·5%). This was probably formed by atmospheric oxidation of a dimethyl-1 : 2-benz-9-anthrone present in the crude hydrocarbon, and recalls the isolation of anthrones from the products of the Elbs reaction in certain other cases (Morgan and Coulson, J., 1929, 2552; 1931, 2324).

3′ : 7-*Dimethyl*-1 : 2-*benzanthracene*, from 1-*m*-toluoyl-2 : 6-dimethylnaphthalene; m. p. 189—190°, from ethyl acetate (Found : C, 93·5; H, 6·2%); *quinone*, m. p. 157°, from ethyl acetate (Found : C, 83·7; H, 4·8%).

The last two analyses were microanalyses by Dr. A. Schoeller.

Summary.

The cancer-producing properties of a hydrocarbon mixture shown to contain 6-*iso*propyl-1 : 2-benzanthracene and probably 6-methyl-1 : 2-benzanthracene, with the possibility of the corresponding 7-substituted compounds, has led to the synthesis of pure 6- and 7-*iso*propyl-1 : 2-benzanthracenes. For comparison, 3- and 10-*iso*propyl-1 : 2-benzanthracenes have also been prepared.

The four β-monomethyl-1 : 2-benzanthracenes have been prepared, so that five of the twelve possible isomerides are now known. Further, five of the six possible β-dimethyl-1 : 2-benzanthracenes have been synthesised. The new hydrocarbons have all been characterised by their quinones and, as far as possible, by their picrates.

I am indebted to the Dyestuffs Group of Imperial Chemical Industries, Ltd., for a supply of sodium *o*-naphthionate, from which the naphthalene-1 : 2-dicarboxy anhydride was prepared. In addition, I am pleased to make acknowledgment of the part played in this investigation by my assistant, Mr. F. Goulden, who prepared many of the materials required, and all the crude methyl derivatives of 1-benzoylnaphthalene, and the crude methyl- and dimethylbenzanthracenes. I have, however, purified and, except in the two cases noted, analysed all the new compounds, and accept full responsibility for all data given.

The catalytic hydrogenation experiments were carried out in a laboratory plant supplied by Technical Research Works, Ltd.

The Research Institute of the Cancer Hospital (Free),
London, S.W. 3.
[*Received, December* 21*st*, 1931.]