

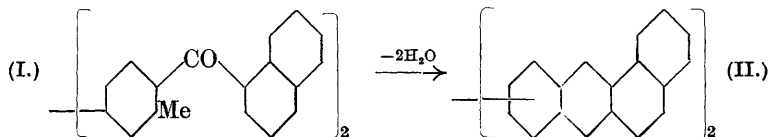
LXVII.—*Polycyclic Aromatic Hydrocarbons. Part IV.* *Condensed Derivatives of 1:2-Benzanthracene.*

By JAMES WILFRED COOK.

It was shown in Part III that, by suitable substitution, a derivative of 1:2:5:6-dibenzanthracene could be obtained having a fluorescence spectrum very similar to that of powerful cancer-producing mixtures of unknown composition. The present investigation was undertaken with the hope of preparing an unsubstituted hydrocarbon having the same fluorescence spectrum, and this hope has been largely realised in the phenanthra-acenaphthene (VII) and phenanthrafluorene (VIII or IX) described below.

In all cases the new hydrocarbons have been obtained by suitable modification of the Elbs dehydration of an *o*-methylbenzophenone to an anthracene derivative.

Condensation of 2-methyl-1-naphthoyl chloride (2 mols.) with diphenyl (1 mol.) led only to the monoketone previously obtained from *p*-phenylbenzoyl chloride and 2-methylnaphthalene (J., 1930, 1088). By using 1-naphthoyl chloride and di-*m*-tolyl, however, 4:4'-*di-α-naphthoyl*-3:3'-*dimethyldiphenyl* (I) was formed, and this was converted by pyrolysis into 1:2:1':2'-*dibenz*-6:6' (or 7:7')-*dianthryl* (II).

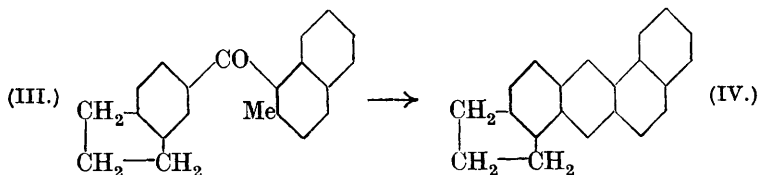


In view of the probability of isomeric change of the type discussed in Part II of this series taking place, it is not possible to say whether the two benzanthracene residues are linked in position 6 or

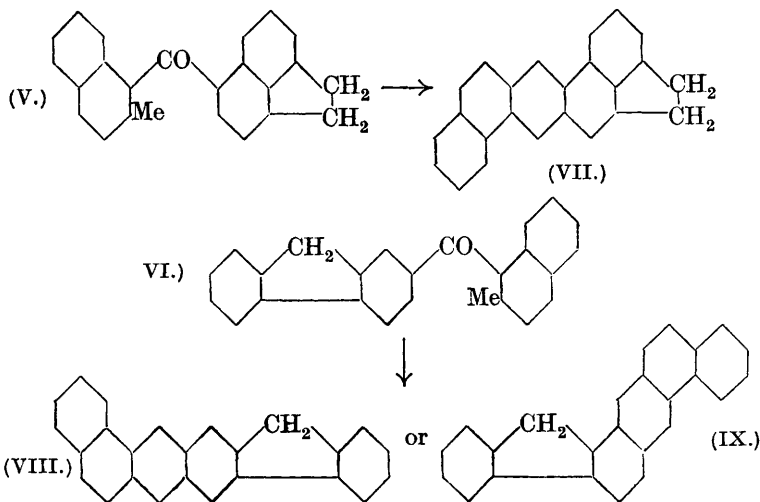
500 COOK : POLYCYCLIC AROMATIC HYDROCARBONS. PART IV.

position 7. The product had a very indefinite m. p. and may be a mixture of both isomerides.

Five-ring Compounds.—The only pure hydrocarbons which have been recognised as definitely carcinogenic are 1:2:5:6-dibenzanthracene and its simple derivatives. Preliminary experiments (Kennaway, private communication) suggest that 6-isopropyl-1:2-benzanthracene also is a weak carcinogenic agent. Considerable interest therefore attaches to cyclopenteno-1:2-benzanthracene (probably IV), which occupies an intermediate position between these two types and was obtained by pyrolysis of the crude ketone (III) resulting from hydrindene and 2-methyl-1-naphthoyl chloride :



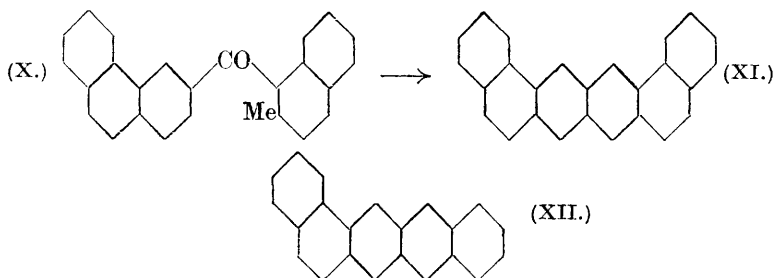
It is known that the carcinogenic mixture obtained from tetralin by the action of aluminium chloride contains partly reduced, condensed aromatic hydrocarbons (Schroeter, *Ber.*, 1924, **57**, 1990), and with the object of obtaining a tetrahydro-derivative of the carcinogenic 1:2:5:6-dibenzanthracene, tetralin was condensed with 2-methyl-1-naphthoyl chloride, and the resulting 2-methyl-5':6':7':8'-tetrahydro-1:2'-dinaphthyl ketone pyrolysed. The high temperature necessary for ring closure resulted in dehydrogenation to such an extent that the only pure hydrocarbon isolated was 1:2:5:6-dibenzanthracene.



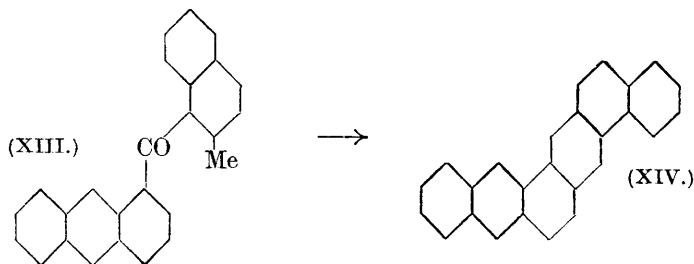
Six-ring Compounds.—The reactive positions in acenaphthene and fluorene are 3 and 2 respectively: the products obtained by condensation of these hydrocarbons with 2-methyl-1-naphthoyl chloride are therefore undoubtedly represented by structures (V) and (VI). By analogy with 2-methyl-1:1'-dinaphthyl ketone (see Part II), dehydration of (V) is probably accompanied by isomerisation so that the resulting *phenanthra-acenaphthene* has formula (VII).

In the case of the ketone (VI) ring closure may have occurred either at position 3 or at position 1 in the fluorene nucleus with the formation of a *phenanthrafluorene* (VIII or IX).

Treatment of 3-*phenanthroyl chloride* with magnesium 2-methyl-1-naphthyl bromide led to the *ketone* (X), which was converted by pyrolysis into 2':3'-*phenanthra-2:3-phenanthrene* (XI), the constitution of which follows from the fact that when 3-phenanthroyl chloride and magnesium *o*-tolyl bromide were used, the hydrocarbon obtained was identical with the 2':3'-*naphtha-2:3-phenanthrene* (XII) described by Clar (*Ber.*, 1929, 62, 1580):



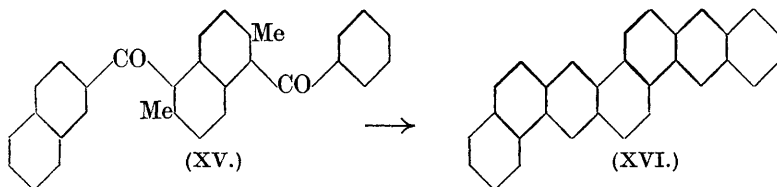
1-Anthroyl chloride also reacted with magnesium 2-methyl-1-naphthyl bromide. The crude ketone (XIII), which could not be obtained crystalline, was converted by pyrolysis into a hydrocarbon, presumably 2':3'-*phenanthra-1:2-anthracene* (XIV; isomerisation and dehydration):



Seven-ring Compounds.—1-Benzoyl-5-(1'-naphthoyl)-2:6-dimethylnaphthalene and 1-benzoyl-5-(2'-naphthoyl)-2:6-dimethylnaphthalene (XV) were readily obtained by the action of benzoyl chloride on

502 COOK : POLYCYCLIC AROMATIC HYDROCARBONS. PART IV.

2 : 6-dimethyl-1 : 1'-dinaphthyl ketone (Cook, this vol., p. 492) and 2 : 6-dimethyl-1 : 2'-dinaphthyl ketone (Fieser and Dietz, *Ber.*, 1929, **62**, 1831) respectively. Both ketones were converted by pyrolysis into hydrocarbons which seemed to be identical. The dehydration of the 1'-naphthoyl compound was evidently preceded by isomerisation into (XV), so the product is 4 : 5-benz-10 : 11-(1' : 2'-naphtha)chrysene (XVI) :



The hydrocarbons (VII), (XIV), and (XVI) all contain the same ring system as the carcinogenic 1 : 2 : 5 : 6-dibenzanthracene.

EXPERIMENTAL.

The condensation between 2-methyl-1-naphthoyl chloride and hydrocarbons was effected, except where otherwise stated, by gradual addition of anhydrous aluminium chloride (1 part) to an ice-cold mixture of acid chloride (1 part), hydrocarbon (1 part), and carbon disulphide (3 parts). After being kept ice-cold for 5—6 hours with occasional shaking, the dark red product was decomposed with ice and hydrochloric acid, and the whole then steam-distilled, first in presence of dilute hydrochloric acid, and then in presence of dilute sodium hydroxide solution. After cooling, the crude ketone was usually obtained as a straw-coloured, brittle, amorphous mass.

For pyrolysis to the hydrocarbons, the ketones were heated in small Pyrex glass retorts at 430—450° until water was no longer liberated ($\frac{1}{2}$ —2 hours). Treatment of the residue varied according to its nature (see individual compounds).

1-p-Phenylbenzoyl-2-methylnaphthalene, and not the corresponding diketone, was obtained when diphenyl (7.7 g.), 2-methyl-1-naphthoyl chloride (21 g.), carbon disulphide (30 c.c.), and anhydrous aluminium chloride (15 g.) were boiled for 3 hours. The product was worked up in the usual way, and the crude ketone recrystallised from acetone-alcohol, then from alcohol alone, and finally from cyclohexane. The resulting colourless needles were shown to consist of the monoketone by direct comparison with an authentic sample.

4 : 4' - Di - α -naphthoyl - 3 : 3' - dimethyldiphenyl (I).—Anhydrous aluminium chloride (20 g.) was added to a mixture of di-*m*-tolyl (9 g.), α -naphthoyl chloride (20 g.), and carbon disulphide (35 c.c.). After being kept for $\frac{3}{4}$ hour at room temperature, the mass was

heated on the water-bath for 3 hours and then worked up in the usual way. The solution of the crude ketone in boiling glacial acetic acid was filtered from amorphous material and set aside for several days. The resulting crystals were recrystallised from glacial acetic acid (yield, 10 g.) and then from methyl ethyl ketone and from benzene (Found: C, 88.1; H, 5.3. $C_{36}H_{26}O_2$ requires C, 88.2; H, 5.3%). This *diketone* formed a cream-coloured crystalline powder, m. p. 159.5–160.5°.

1:2:1':2'-*Dibenz-6:6'(or 7:7')-dianthryl* (II).—The residue from the pyrolysis of the diketone (I; 7.5 g.) was cooled, powdered, and extracted with a little boiling xylene, and the insoluble residue sublimed at about 375°/2 mm. The yellow sublimate (1.9 g.) was very sparingly soluble in all the usual media. For analysis, 0.5 g. was recrystallised from 75 c.c. of boiling tetralin and the resulting yellowish needles were washed with xylene and *cyclohexane* (Found: C, 94.95; H, 5.0. $C_{36}H_{22}$ requires C, 95.2; H, 4.8%). This *hydrocarbon* melted and decomposed above 310°.

cycloPenteno-1:2-benzanthracene (IV).—Acid chlorides condense with hydrindene chiefly in position 5 (von Braun, Kirschbaum, and Schuhmann, *Ber.*, 1920, **53**, 1155; Borsche and Pommer, *Ber.*, 1921, **54**, 102), so the ketone obtained from 2-methyl-1-naphthoyl chloride probably has structure (III). It could not be induced to crystallise and the crude ketone was submitted to pyrolysis, and the residue in the retort distilled in a vacuum. The distillate was recrystallised from *cyclohexane*, benzene, and then twice from ethyl acetate (with animal charcoal). The resulting *hydrocarbon* formed colourless leaflets, m. p. 199–200°, and gave a carmine solution in concentrated sulphuric acid (Found: C, 94.0; H, 6.0. $C_{21}H_{16}$ requires C, 94.0; H, 6.0%). The substance probably has structure (IV), although the 5-membered ring may be condensed with the benzanthracene system in the 6:7-position.

The same *hydrocarbon* was obtained by pyrolysis of the crude ketone formed from magnesium 2-methyl-1-naphthyl bromide and hydrindene-5-carboxy chloride.

2-Methyl-5':6':7':8'-*tetrahydro-1:2'-dinaphthyl Ketone*.—The crude ketone from tetralin and 2-methyl-1-naphthoyl chloride was obtained crystalline from light petroleum (yield, 70%) and purified by recrystallisation from *cyclohexane* and then acetone (Found: C, 87.8; H, 6.7. $C_{22}H_{20}O$ requires C, 88.0; H, 6.7%). This *ketone* formed a colourless crystalline powder, m. p. 122.5–123.5°. Dehydrogenation with sulphur at 210–220° gave a resin, from which 2-methyl-1:2'-dinaphthyl ketone was isolated by repeated crystallisation.

The product of pyrolysis of the above ketone was dissolved in

cyclohexane, and the solution cooled. The crystalline product was sublimed at $290^{\circ}/3-4$ mm. and fractionally crystallised. The only pure substance which could be isolated was 1:2:5:6-dibenzanthracene.

3-(2'-Methyl-1'-naphthoyl)acenaphthene (V).—The crude ketone from acenaphthene and 2-methyl-1-naphthoyl chloride was recrystallised from acetic acid (yield, 65%) and obtained pure by recrystallisation from methyl ethyl ketone and then benzene (Found: C, 89.5; H, 5.4. $C_{24}H_{18}O$ requires C, 89.4; H, 5.6%). This ketone formed a colourless crystalline powder, m. p. $184-185^{\circ}$.

Phenanthra-acenaphthene (VII).—The black residue formed by pyrolysis of (V) was powdered, oily substances were removed by cyclohexane, and the residue was sublimed at $330^{\circ}/3-4$ mm. The yellow sublimate (4 g. from 15 g. of ketone) was twice recrystallised from benzene. The crystals (0.9 g.) were recrystallised from benzene with picric acid (2 g.), and the chocolate-brown needles recrystallised from benzene. The picrate, which depressed the m. p. of the picrate of 1:2:5:6-dibenzanthracene, was decomposed with ammonia, and the hydrocarbon recrystallised from ethyl acetate and then benzene. Phenanthra-acenaphthene formed golden-yellow leaflets, m. p. $231-232^{\circ}$, depressed by 1:2:5:6-dibenzanthracene. It gave a fugitive bluish-violet colour in concentrated sulphuric acid (Found: C, 94.6; H, 5.3. $C_{24}H_{16}$ requires C, 94.7; H, 5.3%).

The benzene liquors from the above preparation contained other substances, which could not be isolated. When the crude product of pyrolysis was distilled, the five-membered ring was partly eliminated and 1:2:5:6-dibenzanthracene formed.

2-(2'-Methyl-1'-naphthoyl)fluorene (VI).—The ketone from fluorene and 2-methyl-1-naphthoyl chloride was recrystallised from glacial acetic acid (yield, 85%) and then from methyl ethyl ketone and from benzene. It formed colourless needles, m. p. $169-170^{\circ}$ (Found: C, 89.8; H, 5.3. $C_{25}H_{18}O$ requires C, 89.8; H, 5.4%).

2:3-Phenanthra-3':2'-fluorene (VIII) or 2:3-Phenanthra-1':2'-fluorene (IX).—The product of pyrolysis of the ketone (VI) was rapidly distilled, and the distillate recrystallised from xylene (yield, 15%). After two further recrystallisations from xylene, the hydrocarbon melted constantly at $302-304^{\circ}$ and formed pale yellow leaflets, sparingly soluble in the usual media. It gave a pale blue solution with a pinkish-red fluorescence in concentrated sulphuric acid, the colour becoming emerald-green on standing or gentle warming (Found: C, 95.1; H, 4.8. $C_{25}H_{16}$ requires C, 94.9; H, 5.1%).

3-Phenanthroyl Chloride.—A suspension of 20 g. of 3-phenanthroic acid (Werner, *Annalen*, 1902, **321**, 323) in thionyl chloride (100 c.c.)

was boiled for 2 hours, and the thionyl chloride removed on the water-bath under diminished pressure. The residue was dissolved in carbon disulphide, and the solution diluted with light petroleum. The *acid chloride* crystallised in colourless silky needles (19.5 g.) and was obtained analytically pure by recrystallisation from benzene-ether. The substance was dried in a vacuum desiccator over phosphoric oxide and potassium hydroxide (Found: C, 74.7; H, 3.8. $C_{15}H_9OCl$ requires C, 74.85; H, 3.7%). The m. p. was 116°.

2':3'-Naphtha-2:3-phenanthrene (XII).—A Grignard solution from *o*-bromotoluene (8 c.c.), magnesium turnings (1.6 g.), and ether (30 c.c.) was added, with agitation, to a suspension of 3-phenanthroyl chloride (16 g.) in dry ether (100 c.c.), kept at -10° . After warming to room temperature during an hour, the whole was boiled for $1\frac{1}{2}$ hours and then decomposed with dilute hydrochloric acid. The ethereal solution was steam-distilled in presence of alkali, and the resinous product, which could not be obtained crystalline, dried and pyrolysed in the usual manner. The residue in the retort was sublimed at $275^\circ/2-4$ mm., and the sublimate twice recrystallised from xylene; it then formed golden-yellow leaflets, m. p. 263—264°. This substance was shown by direct comparison with an authentic sample, kindly supplied by Dr. E. Clar, to consist of 2':3'-naphtha-2:3-phenanthrene.

3-(2'-Methyl-1'-naphthoyl)phenanthrene (X).—A Grignard solution from 1-bromo-2-methylnaphthalene (16.5 g.), magnesium turnings (2.1 g.), and anhydrous ether (120 c.c.) was added gradually to a cold suspension of 3-phenanthroyl chloride (16.5 g.) in dry ether (50 c.c.). The whole was boiled for an hour and worked up in the same manner as the *o*-tolyl ketone. The crude ketone formed a resinous mass, an acetone solution of which deposited crystals during several days. These were collected and recrystallised from methyl ethyl ketone-alcohol and from acetone (Found: C, 89.9; H, 5.0. $C_{26}H_{18}O$ requires C, 90.2; H, 5.2%). This *ketone* formed an almost colourless, crystalline powder, m. p. 145—146°.

2':3'-Phenanthra-2:3-phenanthrene (XI).—The crude pyrolysis product of (X) was sublimed at $300^\circ/3-4$ mm., and the sublimate (yield, 15%) twice recrystallised from xylene. The resulting *hydrocarbon* (XI) formed canary-yellow leaflets, m. p. 341—343°, and gave, with concentrated sulphuric acid, an indigo-blue solution which became emerald-green on gentle warming (Found: C, 94.8; H, 5.0. $C_{26}H_{16}$ requires C, 95.1; H, 4.9%).

A small amount of another *hydrocarbon*, probably isomeric with (XI), was obtained from the xylene liquors of the above preparation. It formed an orange crystalline powder, m. p. 245—248° (Found: C, 95.0; H, 4.7%).

The above phenanthraphenanthrene (XI) was also formed when the crude ketone from 3-phenanthroyl chloride, 2-methylnaphthalene, and anhydrous aluminium chloride was submitted to pyrolysis.

1-Anthroyl Chloride (compare Scholl and Donat, *Ber.*, 1929, **62**, 1297).—A mixture of 1-anthraic acid (15 g.) and thionyl chloride (75 c.c.) was heated under reflux for an hour and the thionyl chloride removed on the water-bath under diminished pressure. The residual oil was dissolved in *cyclohexane*, and the solution well cooled. The acid chloride separated in orange crystals, m. p. 95—97° (yield, 13·7 g.).

2' : 3' - Phenanthra-1 : 2-anthracene (XIV).—Finely powdered 1-anthroyl chloride (12 g.) was added gradually to an ice-cold Grignard solution prepared from 1-bromo-2-methylnaphthalene (11 g.), magnesium turnings (1·4 g.), and anhydrous ether (75 c.c.). The whole was boiled for 2 hours, the product decomposed with dilute hydrochloric acid, and the ethereal solution steam-distilled in presence of alkali. The residual viscous oil, from which no crystalline product could be obtained, was dried in benzene solution, the benzene removed, and the residue pyrolysed.

After cooling, the residue in the retort was powdered, and sublimed at 300—320°/2—3 mm., and the sublimate recrystallised twice from xylene. The *hydrocarbon* (XIV) thus obtained formed canary-yellow needles, m. p. 281—282° (decomp.). It gave no characteristic colour with concentrated sulphuric acid (Found: C, 95·0; H, 5·05. $C_{26}H_{16}$ requires C, 95·1; H, 4·9%).

1-Benzoyl-5-(1'-naphthoyl)-2 : 6-dimethylnaphthalene.—This was prepared from 2 : 6-dimethyl-1 : 1'-dinaphthyl ketone (10 g.), benzoyl chloride (5 c.c.), and anhydrous aluminium chloride (15 g.) in carbon disulphide (50 c.c.) by heating on the water-bath for 12 hours. After decomposition of the product with ice and hydrochloric acid, steam-volatile substances and excess of benzoyl chloride were removed in the usual manner and the residual solid was recrystallised from xylene (yield, 8·9 g.). The *diketone* was obtained analytically pure from ethyl acetate as a colourless microcrystalline powder, m. p. 206—208° (Found: C, 86·7; H, 5·3. $C_{30}H_{22}O_2$ requires C, 86·9; H, 5·3%).

1-Benzoyl-5-(2'-naphthoyl)-2 : 6-dimethylnaphthalene (XV).—This was obtained in the same way as the preceding compound, from 2 : 6-dimethyl-1 : 2'-dinaphthyl ketone (12 g.), benzoyl chloride (5 c.c.), and anhydrous aluminium chloride (20 g.) in carbon disulphide (50 c.c.). The *diketone* (XV) was recrystallised from xylene (yield, 11 g.) and then from methyl ethyl ketone-alcohol. It formed a colourless crystalline powder, m. p. 222—223°, and depressed the

THE ACTION OF AMINES ON 2-SUBSTITUTED SEMICARBAZONES. 507

m. p. of its isomeride (Found : C, 86.6; H, 5.2. $C_{30}H_{22}O_2$ requires C, 86.9; H, 5.3%).

4 : 5-Benz-10 : 11-(1' : 2'-*naphtha*)*chrysene* (XVI).—The aforesaid diketone (XV) was pyrolysed in the usual manner, and the crude product sublimed at $375^\circ/2$ mm. The canary-yellow sublimate (yield, 40%) was almost insoluble in all the usual media. An analytical sample was obtained by recrystallisation from much tetralin and then formed golden-yellow leaflets, m. p. $435\text{--}440^\circ$ (decomp.) (Found : C, 95.1; H, 4.8. $C_{30}H_{18}$ requires C, 95.2; H, 4.8%).

A hydrocarbon which seemed in every way identical with this benznaphthachrysene was formed by the pyrolysis of 1-benzoyl-5-(1'-naphthoyl)-2 : 6-dimethylnaphthalene.

Attempts to prepare diketones by condensing 2 : 7-dimethyl-1 : 1'-dinaphthyl ketone and 2 : 7-dimethyl-1 : 2'-dinaphthyl ketone with benzoyl chloride were fruitless.

The author has pleasure in making acknowledgment to Mr. F. Goulden for much assistance in the preparation of material.

THE CANCER HOSPITAL RESEARCH INSTITUTE,

LONDON, S.W.3.

[Received, January 6th, 1931.]