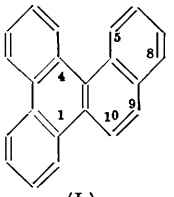
34. *Polycyclic Aromatic Hydrocarbons. Part XVI.* 1 : 2 : 3 : 4-*Dibenzphenanthrene.*

By C. L. HEWETT.

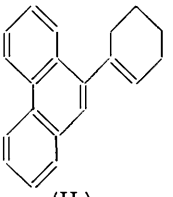
1 : 2 : 3 : 4-*Dibenzphenanthrene* has been synthesised by the Pschorr method from *o*-amino-α-9-phenanthrylcinnamic acid. The cyclisation of 1-(β-9′-*phenanthrylethyl*)-Δ^1-cyclo*hexene* has been carried out, but has been shown to give a *spiran* and not the expected octahydrodibenzphenanthrene. The cyclisation of 1-(β-9′-phenanthrylethyl)-Δ^1-*cyclo*pentene is discussed.

THE three pentacyclic hydrocarbons composed entirely of six-membered aromatic rings which have not yet been described are all derivatives of the feebly carcinogenic hydrocarbon 3 : 4-benzphenanthrene. Furthermore, 2-methyl-3 : 4-benzphenanthrene (Hewett, J., 1936, 596) is a carcinogenic hydrocarbon of considerable potency, as it produces tumours more rapidly than 1 : 2 : 5 : 6-dibenzanthracene, and almost as rapidly as the very active compounds of the cholanthrene and 3 : 4-benzpyrene groups (Bachmann *et al.*, *Proc. Roy. Soc.*, 1937, *B*, 123, 349).

Hence, although most of the existing carcinogenic compounds are related to 1 : 2-benzanthracene, the above considerations suggest that it may be possible to obtain a new group of active compounds, derived from 3 : 4-benzphenanthrene. 1 : 2 : 3 : 4-*Dibenzphenanthrene* (I) has now been synthesised and is being tested for carcinogenic activity. It bears the same relationship to 2-methyl-3 : 4-benzphenanthrene as 1 : 2 : 5 : 6-dibenzanthracene does to the less potent 5-methyl-1 : 2-benzanthracene.



(I.)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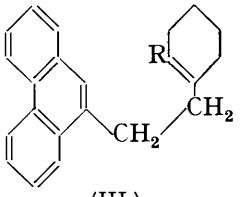

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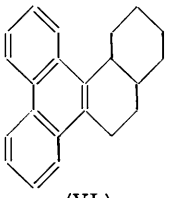
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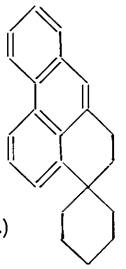
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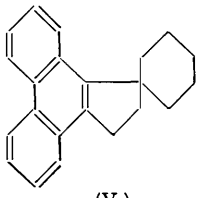

(V.)

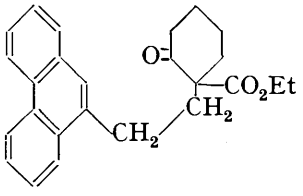
Bergmann and Bergmann (*J. Amer. Chem. Soc.*, 1937, **59**, 1443) attempted to synthesise 1 : 2 : 3 : 4-dibenzphenanthrene by the Diels–Alder diene reaction. They found that 1-9′-phenanthryl-Δ^1-*cyclo*hexene (II) failed to react with maleic anhydride, although the corresponding *cyclo*pentene derivative reacted smoothly.

An attempt to obtain the desired ring system by the cyclisation of 1-(β-9′-*phenanthrylethyl*)-Δ^1-cyclo*hexene* (III; R = H) by means of aluminium chloride has likewise met with no success. Instead of the desired octahydrodibenzphenanthrene (VI), the only product isolated was a *spiran* (probably IV, although V is not excluded), which was obtained in 80% yield. This spiran was recovered unchanged after 24 hours' heating with selenium at 300°, treatment which would be expected to dehydrogenate (VI) but not (IV) or (V) (Cook and Hewett, J., 1933, 1109; 1934, 372). Avoidance of spiran formation in analogous cases has been achieved by the introduction of a methyl group, which is subsequently expelled by dehydrogenation, but in view of the unsatisfactory results obtained by Cook, Haslewood, and Robinson in the cyclisation of 2-methyl-1-(β-1′-acenaphthylethyl)-Δ^1-

*cyclo*hexene (J., 1935, 670) the cyclisation of the corresponding 2-methyl-*cyclo*hexene (III; R = Me) was not attempted.

Subsequent to these experiments, Bergmann and Blum-Bergmann (*J. Amer. Chem. Soc.*, 1936, **58**, 1678) claimed to have obtained *cyclo*pentenotriphenylene by the cyclisation of 1-(β-9′-phenanthrylethyl)-Δ^1-*cyclo*pentene (analogous to III) by means of aluminium chloride, followed by dehydrogenation. In view of the results now described, it would appear that their compound, m. p. 105·5—107°, regarded by them as tetrahydro*cyclo*pentanotriphenylene, is in fact a spiran and that its dehydrogenation product, alleged to be *cyclo*pentenotriphenylene, is actually a methyl-3 : 4-benzpyrene (compare Cook and Hewett, J., 1934, 372). This would accord with the small yield of product and the resistance to dehydrogenation, for some of the tetrahydro-compound was recovered after 20 hours' heating with selenium at 330—340°. Also the colours of the dehydrogenation product and of its picrate are more in keeping with the benzpyrene structure.

The cyclisation of ethyl 2-(β-9′-phenanthrylethyl)*cyclo*hexanone-2-carboxylate (VII) by boiling 65% sulphuric acid was attempted, but no crystalline products could be isolated.



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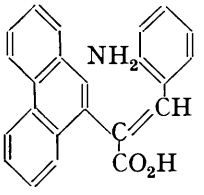

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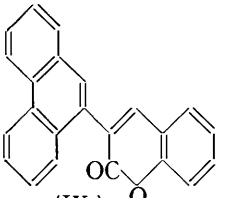

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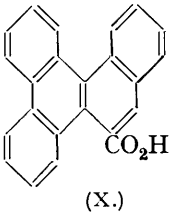

(X.)

The synthesis of 1 : 2 : 3 : 4-dibenzphenanthrene was eventually accomplished from 9-phenanthrylacetic acid by the Pschorr reaction. An attempted simplification of the preparation of this acid by the oxidation of 9-allylphenanthrene (the preparation of which was published by Bergmann and Blum-Bergmann, *loc. cit.*, while this work was in progress) by means of potassium permanganate in acetone solution (compare the oxidation of 1-allylnaphthalene; Keach, *J. Amer. Chem. Soc.*, 1933, **55**, 2974; Higginbottom and Short, *Rec. trav. chim.*, 1934, **53**, 1141) was impracticable owing to the simultaneous formation of considerable amounts of 9-phenanthroic acid, presumably from the propenylphenanthrene which is known to be formed by migration of the double bond under the influence of alkali (Bergmann and Blum-Bergmann). Hill and Short (J., 1937, 260), however, have shown that arylacetic acids can be obtained in yields of 40% by oxidation of the corresponding allyl compounds by means of potassium permanganate in the presence of acetic acid, only traces of the arylcarboxylic acids being obtained. The procedure of Mosettig and van de Kamp (*J. Amer. Chem. Soc.*, 1933, **55**, 2995) for the preparation of 9-phenanthrylacetic acid was improved by using a simpler route to 9-phenanthraldehyde, which was obtained in excellent yield by hydrolysis of the acetal resulting from interaction of ethyl orthoformate with 9-phenanthrylmagnesium bromide. Miller and Bachmann (*J. Amer. Chem. Soc.*, 1935, **57**, 769) have prepared 9-phenanthraldehyde by this method, but in yields of only 46%.

o-*Nitro*-α-9-*phenanthrylcinnamic acid* was reduced to the *amino-acid* (VIII) by means of ferrous hydroxide, and decomposition with copper powder at 50° of the sparingly soluble diazonium sulphate obtained from this amino-acid led to a mixture of acids, from which the hydroxy-acid was separated in the form of its *lactone* (IX) by means of methyl-alcoholic hydrogen chloride. 1 : 2 : 3 : 4-*Dibenz*-10-*phenanthroic acid* (X), which was not esterified by this treatment, was then readily isolated. It was decarboxylated to 1 : 2 : 3 : 4-dibenzphenanthrene by copper powder in boiling quinoline. The hydrocarbon, obtained in good yield, was purified through its *picrate*. On oxidation with sodium dichromate it passed into 1 : 2 : 3 : 4-*dibenzphenanthraquinone*, the ortho-quinonoid character of which was shown by its conversion into an *azine* by *o*-phenylenediamine.

Experimental.

1-(β-9′-*Phenanthrylethyl*)-Δ^1-cyclo*hexene* (III; R = H).—*cyclo*Hexanone (6 g.) was added to an ice-cold Grignard solution prepared from β-9-phenanthrylethyl chloride (Bergmann and

Blum-Bergmann, *J. Amer. Chem. Soc.*, **1936**, **58**, 1678) (10·5 g.), magnesium (1·1 g.), ether (35 c.c.), and benzene (15 c.c.). After 2 hours' boiling, the product was decomposed with ice and ammonium chloride, the ethereal solution washed, dried, and evaporated, and the residue distilled. The fraction (10·5 g.), b. p. 220—240°/0·4 mm., was heated with potassium hydrogen sulphate (15 g.) at 160—180° for 1 hour, and the product extracted with ether and distilled, b. p. 200—220°/0·5 mm. (9 g.). The *hydrocarbon* was purified by crystallisation from alcohol of its yellow picrate, m. p. 120—121°, and then formed a viscous oil, b. p. 205—206°/0·4 mm. (Found : C, 91·3; H, 7·9. $C_{22}H_{22}$ requires C, 92·2; H, 7·8%).

Cyclisation. A solution of the unsaturated hydrocarbon (5·2 g.) in carbon disulphide (52 c.c.) was treated at 0° with aluminium chloride (5·2 g.) and kept at 2—3° for 5 hours. Ice and hydrochloric acid were then added and the carbon disulphide solution was washed, dried, and evaporated. The residue was distilled over sodium, b. p. 205—210°/0·3 mm., and the solid distillate (4·6 g.) recrystallised from ethyl alcohol. The product, probably *dihydrobenzanthrene*-spirocyclo*hexane* (IV), formed small colourless plates (3 g.), m. p. 131—132° (Found : C, 92·3; H, 7·8. $C_{22}H_{22}$ requires C, 92·2; H, 7·8%).

β-9-*Phenanthrylethyl Bromide.*—Phosphorus tribromide (50 g.) was slowly added to a solution of β-9-phenanthrylethyl alcohol (Bergmann and Blum-Bergmann, *loc. cit.*) (38 g.) in carbon tetrachloride (100 c.c.) at 60°. After 20 minutes' heating, the solution was cooled, washed with water and dilute sodium carbonate solution, dried, and distilled. The fraction (11 g.), b. p. 200—210°/0·5 mm., was twice recrystallised from ethyl alcohol. β-9-*Phenanthrylethyl bromide* formed colourless needles, m. p. 86—86·5° (Found : C, 67·8; H, 4·8. $C_{16}H_{13}Br$ requires C, 67·4; H, 4·6%).

Ethyl 2-(β-9′-*Phenanthrylethyl*)cyclo*hexanone-2-carboxylate* (VII).—The potassio-compound prepared from potassium (2·3 g.), ethyl *cyclo*hexanone-2-carboxylate (9·8 g.), and toluene (100 c.c.) was treated with β-9-phenanthrylethyl bromide (11·2 g.) at the b. p. for 60 hours. The whole was then washed with water, the toluene removed, and the residue heated to 240°/0·4 mm. in order to remove low-boiling products and dissolved in ether. The filtered solution was evaporated; the residual keto-ester (13 g.) gave on hydrolysis with potassium hydroxide in aqueous alcohol α-(β-9-*phenanthrylethyl*)*pimelic acid*, m. p. 86—90°, after three crystallisations from benzene (Found : C, 76·1; H, 6·75. $C_{23}H_{24}O_4$ requires C, 75·8; H, 6·65%).

The keto-ester (VII) (8·5 g.) was refluxed with sulphuric acid (100 c.c.) and water (100 c.c.) for 16 hours. The product was extracted with ether and distilled, b. p. 220—230°/0·3 mm. (1·7 g.). After dehydrogenation with selenium (1·5 g.) at 330° for 24 hours, only 0·3 g. of non-crystallisable material was obtained.

Oxidation of 9-*Allylphenanthrene.*—A solution of allylphenanthrene (17 g.) in acetone (170 c.c.) was cooled in a freezing mixture, and potassium permanganate (52 g.) slowly added. After some hours the solution was diluted with water and decolourised with sulphur dioxide. The whole was extracted with ether, and the crude acids separated by means of sodium carbonate solution. The mixture of acids was esterified with methyl-alcoholic hydrogen chloride, and the esters distilled, b. p. 174—189°/0·3 mm. (12 g.). This mixture, after solidifying, was crystallised from methyl alcohol, giving long colourless needles (3·5 g.), m. p. 114—115°, of methyl phenanthrene-9-carboxylate (Shoppee, J., 1933, 39, gives m. p. 115°) (Found : C, 81·3; H, 5·1. Calc. : C, 81·6; H, 5·0%). Hydrolysis yielded 9-phenanthroic acid, m. p. 257—258° alone or mixed with an authentic specimen.

The mother-liquors of the ester were distilled, and the fraction, b. p. 175—185°/0·5 mm., collected (7 g.). On hydrolysis with alcoholic potassium hydroxide this gave a mixture of acids (6 g.), from which sodium 9-phenanthrylacetate was obtained by solution in ethyl alcohol (70 c.c.) and addition of sodium hydroxide (1·5 g.) dissolved in a little water. After crystallisation from acetic acid the 9-phenanthrylacetic acid (3 g.) had m. p. 221—222°, not depressed by an authentic specimen but depressed by 9-phenanthroic acid.

9-*Phenanthraldehyde* (compare Miller and Bachmann, *loc. cit.*).—The Grignard solution prepared from 9-bromophenanthrene (104 g.), magnesium (10 g.), anisole (200 c.c.), and ether (180 c.c.) (Shoppee, *loc. cit.*) was cooled in ice and treated with freshly distilled ethyl orthoformate (65·2 g.). The mixture, after being kept in ice for ¼ hour and boiled for 2 hours, was decomposed with ice and hydrochloric acid, the volatile matter distilled in steam, the residue boiled for ½ hour, and the solid aldehyde extracted with hot benzene, dried, and distilled, b. p. 180—190°/0·5 mm. (71 g.). After crystallisation from alcohol it had m. p. 99—100° (61 g., a further amount being recovered from the liquor).

o-*Nitro*-α-9-*phenanthrylcinnamic Acid.*—Sodium 9-phenanthrylacetate (62 g., which crystallised when the calculated amount of sodium hydroxide was added to an alcoholic solution of the

acid), acetic anhydride (400 c.c.), and *o*-nitrobenzaldehyde (55 g.) were heated at 125—130° for 7½ hours and poured into 1½ l. of water. After 12 hours, the solution was decanted, and the red resin digested with dilute aqueous ammonia for 2 hours on the water-bath. The solution was boiled (charcoal), filtered, and acidified. The acid was redissolved in 1 l. of N-ammonia and allowed to cool slowly; the ammonium salt, which separated, was collected, dissolved in hot water, and acidified. The liquor of the ammonium salt contained only *o*-nitrocinnamic acid. o-*Nitro*-α-(9-*phenanthryl*)*cinnamic acid* (41·5 g.) separated from alcohol in canary-yellow needles, m. p. 214—215° (Found: C, 74·1; H, 4·4. $C_{23}H_{15}O_4N$ requires C, 74·8; H, 4·1%).

o-*Amino*-α-(9-*phenanthryl*)*cinnamic Acid* (VIII).—The foregoing nitro-acid (40·5 g.) was heated on the water-bath with ferrous sulphate (400 g.), aqueous ammonia (200 c.c.; *d* 0·880), and water (2 l.) for 2 hours. The ferric hydroxide sludge was extracted ten times with boiling 2% aqueous ammonia, and the combined extracts together with the original filtrate were made just slightly acid with dilute acetic acid. The *amino-acid* was converted by potassium carbonate solution into the potassium salt, which was recrystallised from dilute potassium carbonate solution and decomposed with acetic acid. The free acid (20 g.) separated from benzene as a yellow crystalline powder, m. p. 195—196° (Found: C, 81·7; H, 5·3. $C_{23}H_{17}O_2N$ requires C, 81·4; H, 5·05%).

1 : 2 : 3 : 4-*Dibenz*-10-*phenanthroic Acid* (X).—The amino-acid (16 g.) was made into a paste with water (50 c.c.), potassium carbonate (8·2 g.), and potassium nitrite (5·5 g.), cooled, and slowly run into 5N-sulphuric acid (400 c.c.) at 0°. Copper powder was added and, when the evolution of nitrogen ceased, the whole was warmed at 50° for 1 hour. A solution of the solid deposit in aqueous sodium carbonate solution was boiled (charcoal), filtered, and acidified and the acids were extracted in ether, dried, recovered, and treated with methyl alcohol and hydrogen chloride. After dilution with water the whole was shaken with ether, the ethereal solution twice extracted with dilute sodium hydroxide solution, and the extract acidified. The acid was purified through the sodium salt and after two crystallisations from acetic acid 1 : 2 : 3 : 4-*dibenz*-10-*phenanthroic acid* (X) was obtained (3·4 g.), m. p. 266—267°. A portion was sublimed at 260°/0·5 mm.; it then separated from acetic acid in pale yellow needles, m. p. 267—268° (Found: C, 85·3; H, 4·5. $C_{23}H_{14}O_2$ requires C, 85·7; H, 4·4%).

The neutral fraction obtained from the ether on evaporation was triturated with acetone, and the solid thrice crystallised from xylene; it formed colourless plates of 3-(9′-*phenanthryl*)-*coumarin* (IX) (Found: C, 85·8; H, 4·5. $C_{23}H_{14}O_2$ requires C, 85·7; H, 4·4%).

1 : 2 : 3 : 4-*Dibenzphenanthrene* (I).—The acid (X) (3·2 g.) was dissolved in quinoline (30 c.c.) and boiled for 3 hours with copper bronze (1·5 g.). The solution was diluted with ether, filtered from copper, washed with dilute hydrochloric acid and with dilute sodium hydroxide solution, dried, and evaporated. The residue (2·7 g.) was converted into the picrate with picric acid (2·7 g.) in acetic acid solution, the picrate decomposed, and the hydrocarbon distilled from an oil-bath at 270—280°/0·3 mm. After recrystallisation from glacial acetic acid 1 : 2 : 3 : 4-*dibenzphenanthrene* (I) formed colourless needles (1·85 g.), m. p. 114·5—115° (Found: C, 94·85; H, 5·2. $C_{22}H_{14}$ requires C, 94·9; H, 5·1%).

The *picrate* separated in scarlet needles, m. p. 140—140·5°, from acetic acid containing a little picric acid (Found: C, 66·0; H, 3·5. $C_{22}H_{14},C_6H_3O_7N_3$ requires C, 66·25; H, 3·4%).

1 : 2 : 3 : 4-*Dibenzphenanthraquinone*.—The hydrocarbon (0·1 g.) was dissolved in acetic acid (2 c.c.) and boiled with sodium dichromate (0·2 g.) for 5 minutes. Water was added, and the red precipitate filtered off, dried, and recrystallised twice from toluene and once from ethyl acetate; it then formed bright red needles, m. p. 237—238° (Found: C, 85·5; H, 4·1. $C_{22}H_{12}O_2$ requires C, 85·7; H, 3·9%). The *azine* derivative, prepared with *o*-phenylenediamine in acetic acid solution, recrystallised from toluene in canary-yellow needles, m. p. 242—243° (Found: C, 88·2; H, 4·3; N, 7·7. $C_{28}H_{16}N_2$ requires C, 88·4; H, 4·2; N, 7·4%).

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