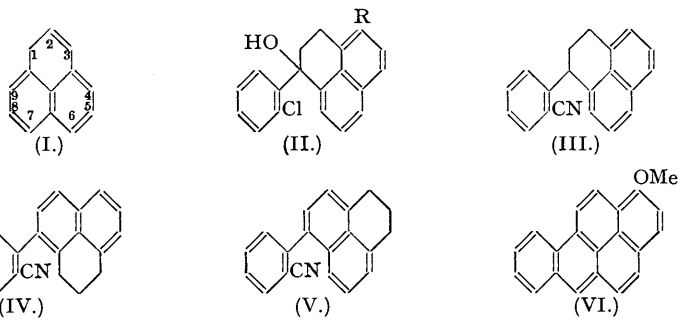
379. *Polycyclic Aromatic Hydrocarbons. Part XXXV. Isomerization in the Perinaphthene Series.*

By G. M. Badger, W. Carruthers, and J. W. Cook.

An example of isomerization in the perinaphthene series, leading to the conversion, by dehydration, of the *methoxy-carbinol* (II; R = OMe) into the *ketone* (VIII) is described. The implications of this in regard to the tautomeric mobility of the perinaphthene system are discussed.

The possibility of tautomerism between six structures in the perinaphthene system (I) * was suggested by Klyne and Robinson (*J.*, 1938, 1991). Although the *reversible* changes which this implies have not yet been realised, the double-bond mobility which is inherent in such a conception was later demonstrated by Fieser and Gates (*J. Amer. Chem. Soc.*, 1940, **62**, 2335), who found, that when the carbinol (II; R = H) was submitted to a series of reactions involving dehydration, reduction, and replacement of the chlorine by a cyano-group, without isolation of intermediates, two products were obtained which were shown to have the structures (IV) and (V). These products must have arisen by a bond rearrangement in the initial product of dehydration, and there was no evidence of the formation of the normal product, unaccompanied by bond-migration. It was suggested that the driving force in the rearrangement was the tendency to conjugation between the chlorophenyl group and a naphthalene system.



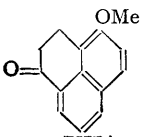
We have now observed a similar rearrangement, which has frustrated an attempt to synthesise 10-methoxy-3 : 4-benzpyrene (VI), one of the (methylated) metabolites of the carcinogenic parent hydrocarbon. By condensation of 4-*methoxyperinaphthan*-1-*one* (VII) with *o*-chlorophenylmagnesium bromide there was obtained 4-*methoxy*-1-*o*-*chlorophenylperinaphthan*-1-*ol* (II; R = OMe). This carbinol, on treatment with a little iodine in boiling light petroleum or with cold dilute methanolic hydrogen chloride, underwent not only dehydration but also rearrangement and demethylation to give the *ketone* (VIII) as the sole product. A Zeisel determination showed the absence of a methoxyl group, and the substance did not decolourise bromine water or dilute permanganate. Moreover, the carbonyl function with an adjacent methylene group was established by preparation of a *semicarbazone*, a 2 : 4-*dinitrophenylhydrazone*, and a *benzylidene* derivative. The formation of such a ketone may be interpreted as dehydration of the carbinol (II; R = OMe) to (IX), followed by rearrangement to (X). (X) would be the ether of an enol, and its hydrolysis and conversion into (VIII) under the experimental conditions used would not be surprising. It is of considerable interest that the ketone (VIII) was the only product formed and that it was not accompanied by compounds of type (XI) structurally analogous to an intermediate leading to one of the compounds (IV) isolated in the example studied by Fieser and Gates (*loc. cit.*).

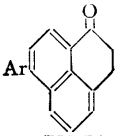
This result supports the conception of Klyne and Robinson (*loc. cit.*) of the tautomeric character of the perinaphthene system, for if (X) and (XI), for example, are regarded as in tautomeric equilibrium then the equilibrium would be disturbed by conversion of (X) into the ketone (VIII), so that ultimately (XI) would be wholly converted into (VIII).

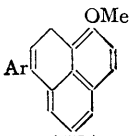
The starting point in the synthesis of the methoxyperinaphthanone (VII) was 2-methoxynaphthalene, which was chloromethylated by a modification of the method of Cook, Downer, and Hornung (*J.*, 1941, 502); the product was condensed with ethyl malonate to give *ethyl*

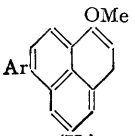
* To avoid anomalies in naming certain derivatives perinaphthene will be numbered as shown in (I). —Ed.

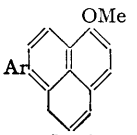
2-*methoxy*-1-*naphthylmethylmalonate*. Hydrolysis and decarboxylation then gave β-(2-methoxy-1-naphthyl)propionic acid (XIII). This method represents a considerable improvement on


(VII.)

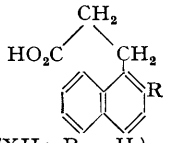

(VIII.)

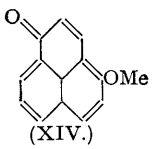

(IX.)
[Ar = C_6H_4Cl]

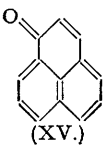

(X.)


(XI.)

that used by Barger and Starling (*J.*, 1911, 2030) who obtained the same acid, in poor yield, by reduction of the corresponding acrylic acid. For the cyclisation of this acid (XIII) we investigated three methods. With anhydrous hydrogen fluoride (cf. Fieser and Gates, *loc. cit.*), 4-methoxyperinaphthan-1-one (VII) was obtained in good yield, and its structure was confirmed by the preparation of an *oxime* and a *benzylidene* derivative. The same product was also obtained from the acid chloride of (XIII) with stannic chloride. This is of some interest, for it has been found that although the cyclisation of the methoxy-free acid (XII) proceeds normally with hydrogen fluoride to give the colourless perinaphthanone, cyclisation with stannic chloride or aluminium chloride gives the yellow perinaphthenone (XV) (Fieser and Gates, *loc. cit.*; Cook and Hewett, *J.*, 1934, 368). The compound (XV) is basic and readily dissolves in concentrated hydrochloric acid. The ketone (VII) obtained in the present work was yellow, and in view of the above it seemed likely that the colour was due to contamination with some of the dehydrogenated product (XIV). It was, however, not possible to remove the colour, either by extraction of a benzene solution with hydrochloric acid or by chromatography on alumina.


(XII; R = H.)
(XIII; R = OMe.)


(XIV.)


(XV.)

A compound of structure (VII) has already been reported by Barger and Starling (*loc. cit.*) having been obtained, in small yield, by cyclisation of the acid (XIII) with phosphoric oxide. This product was clearly not identical with the ketone described above, and the cyclisation with phosphoric oxide has therefore been re-investigated. The crude product was found to be a complex mixture, and two crystalline products were isolated. One of these has been identified as perinaphthenone (XV), by comparison with an authentic specimen. The formation of this compound requires demethylation and dehydration of (VII), with bond rearrangement. The second crystalline product isolated was apparently identical with the substance isolated by Barger and Starling. Its solubility in hydrochloric acid and its other properties suggest that it is 4-*methoxyperinaphthen*-1-*one* (XIV), and not 4-methoxyperinaphthan-1-one (VII) as suggested by Barger and Starling.

If the explanation which is postulated for the rearrangements discussed above is correct, then it is conceivable that the carbinols which should result from interaction of (VII) with methylmagnesium iodide or 9-anthranylmagnesium bromide would undergo dehydration without rearrangement to give compounds of type (IX). In the latter case it was anticipated that steric inhibition of resonance would prevent true conjugation and hence prevent rearrangement. Attempts to test this hypothesis were unsuccessful. Methylmagnesium iodide reacted with (VII) to give an uncrystallisable oil, and the dehydration product was also an oil. Anthranylmagnesium bromide did not react with the ketone (VII), for, after decomposition with water, only anthracene was isolated.

Experimental.

2-*Methoxy*-1-*chloromethylnaphthalene*.—In our hands, the method of Cook, Downer, and Hornung (*loc. cit.*) led to insoluble high-melting material, and a slightly less vigorous method was therefore used. Hydrogen chloride was passed through an ice-cold suspension of paraformaldehyde (18 g.) in glacial acetic acid (250 c.c.), until a clear solution was obtained. A suspension of 2-methoxynaphthalene (45 g.) in glacial acetic acid (400 c.c.) was gradually added to the cold solution, with shaking. After 2 hours at room temperature, the crystalline product was collected and recrystallised from benzene–light

petroleum (b. p. 60—80°). 2-Methoxy-1-chloromethylnaphthalene formed colourless rhombs (40 g.), m. p. 117—120° (decomp.). After further recrystallisation, it had m. p. 122—123° (decomp.) [lit., 120° (decomp.)].

Ethyl 2-Methoxy-1-naphthylmethylmalonate.—2-Methoxy-1-chloromethylnaphthalene (10 g.) in dry benzene (15 c.c.) was added to a solution of ethyl sodiomalonate (from ethyl malonate 10 g., sodium 1·4 g., dry benzene 50 c.c., and absolute ethanol 20 c.c.), and the mixture heated under reflux for 3 hours. The cooled solution was washed with, successively, dilute acid, sodium carbonate solution, and water. The oil obtained after removal of the solvent and the excess of ethyl malonate (b. p. 200—205°/2·5 mm.; 11·9 g.) solidified when cooled in presence of a little alcohol. *Ethyl 2-methoxy-1-naphthylmethylmalonate* formed colourless hexagonal plates, m. p. 56°, from ethanol (Found: C, 69·3; H, 6·9. $C_{19}H_{22}O_5$ requires C, 69·1; H, 6·7%).

β-(2-Methoxy-1-naphthyl)propionic Acid (XIII).—The above ester (11 g.) was hydrolysed by boiling for 2 hours with aqueous alcoholic potassium hydroxide. The *malonic acid* (10 g.) crystallised from water as a colourless micro-crystalline powder, m. p. 174—175° (decomp.) (Found: C, 65·6; H, 4·6. $C_{15}H_{14}O_5$ requires C, 65·7; H, 5·1%). This (9·5 g.) was decarboxylated by heating it at 190° for a few minutes (until evolution of carbon dioxide ceased). The residual oil, crystallised from acetic acid (charcoal), gave β-(2-methoxy-1-naphthyl)propionic acid as colourless flat needles, m. p. 131° (*lit.*, 128°) (Found: C, 73·0; H, 6·0. Calc. for $C_{14}H_{14}O_3$: C, 73·0; H, 6·1%). In a large-scale run, in which the malonic ester was not isolated but was directly hydrolysed and the product decarboxylated, 80 g. of chloromethyl compound gave 72 g. of pure propionic acid, an overall yield of 80%.

Cyclisation with Hydrogen Fluoride.—The above acid (1·5 g.) was left in contact with anhydrous hydrogen fluoride, at room temperature, for 3½ hours. The red solution was poured on ice, and the yellow solid collected and extracted with warm dilute sodium carbonate. No acid was recovered from this extract. The neutral material was dissolved in benzene, and the solution was repeatedly extracted with fresh portions of concentrated hydrochloric acid. The benzene solution remained coloured, and it was accordingly passed through a column of alumina and eluted with benzene. No evidence was obtained that the yellow colour was due to an impurity. Evaporation of the benzene gave *4-methoxyperinaphthan-1-one* (VII) as yellow plates, m. p. 65° (1·1 g., 80%) (Found: C, 79·4; H, 5·7. $C_{14}H_{12}O_2$ requires C, 79·2; H, 5·7%). The *oxime*, prepared by the method of Cook, Hewett, and Lawrence (*J.*, 1936, 79), formed pale yellow needles, m. p. 157—159° (decomp.), from ethanol (Found: C, 73·8; H, 5·6; N, 6·0. $C_{14}H_{13}O_2N$ requires C, 74·0; H, 5·7; N, 6·2%).

The *benzylidene* derivative was prepared by treating a mixture of the ketone (0·5 g.) and benzaldehyde (1 g.) in ethanol (5 c.c.) with potassium hydroxide (1 g.) in ethanol (10 c.c.). After 20 hours at room temperature, the mixture was acidified with acetic acid, diluted with water, and extracted with benzene. Removal of the benzene gave an oil which deposited a solid material (0·15 g.) when treated with alcohol and, after crystallisation from benzene–light petroleum (b. p. 60—80°), this was obtained as orange-red prisms, m. p. 172—173° (Found: C, 84·2; H, 5·7. $C_{21}H_{16}O_2$ requires C, 84·0; H, 5·4%).

Cyclisation with Stannic Chloride.—A cooled mixture of the methoxynaphthylpropionic acid (XIII) (10 g.) and dry thiophen-free benzene (100 c.c.) was treated with phosphorus pentachloride (8 g.). After 1 hour at room temperature, the mixture was heated on the steam-bath for 5 minutes. After cooling in ice, the mixture was treated with stannic chloride (10 c.c.) in dry thiophen-free benzene (100 c.c.). The reaction was allowed to proceed for 4 hours, after which the product was hydrolysed with ice and hydrochloric acid, and the benzene layer separated. After being washed with concentrated hydrochloric acid, sodium carbonate solution, and water, it was dried and evaporated. Methoxyperinaphthanone (8 g.), m. p. 65°, identical (mixed m. p.) with the product obtained as above, was obtained by recrystallisation from light petroleum. The identity of the products was confirmed by comparison of the oximes.

Cyclisation with Phosphoric Oxide.—Methoxynaphthylpropionic acid (2 g.) in dry benzene (20 c.c.) was treated with phosphoric oxide (10 g.), and the mixture heated for 2 hours on the water-bath and then kept overnight at room temperature. After treatment with ice, the benzene solution was separated, washed with sodium carbonate (0·6 g. of acid recovered) and then with water, and dried. Removal of the solvent gave a dark oil which deposited some crystals when kept. Recrystallisation from benzene–light petroleum (60—80°) gave *4-methoxyperinaphthen-1-one* (XIV) as orange yellow needles, m. p. 142—143° (Barger and Starling give m. p. 135°) (Found: C, 79·9; H, 4·9. $C_{14}H_{10}O_2$ requires C, 80·0; H, 4·8%). The oil remaining after the removal of the crystalline material was passed through a column of alumina. Several bands were obtained. A pale yellow band having a bright yellow fluorescence in ultra-violet light was removed by elution with benzene; after the solvent had been removed, the yellow residue (10 mg.) was further recrystallised from light petroleum (60—80°) from which yellow needles, m. p. 150°, separated; this was perinaphthenone (XV) (mixed m. p., 150—152°, with an authentic specimen, m. p. 153°). The other bands of the chromatogram yielded small amounts of uncrystallisable oils, and were not further examined.

4-Methoxy-1-o-chlorophenylperinaphthan-1-ol (II; R = OMe).—A solution of 4-methoxyperinaphthan-1-one (12 g.) in dry thiophen-free benzene (200 c.c.) was slowly added to a Grignard solution, from magnesium (2·3 g.) and *o*-chlorobromobenzene (18 g.) in ether (200 c.c.) with constant stirring. A yellow solid separated. After being kept overnight at room temperature, the mixture was heated under reflux for 1 hour and then decomposed with aqueous ammonium chloride. The ethereal solution was separated and washed with dilute sodium hydroxide until the washings were no longer red, and then with water. The oil remaining after removal of the ether was steam-distilled to remove excess of *o*-chlorobromobenzene. The resulting oil deposited a yellow solid (5 g.) when triturated with light petroleum. After crystallisation from methanol (charcoal) and then from benzene–light petroleum (b. p. 60—80°), *4-methoxy-1-o-chlorophenylperinaphthan-1-ol* was obtained as colourless prisms, m. p. 151—152° (Found: C, 74·1; H, 5·5; OMe, 9·6. $C_{20}H_{17}O_2Cl$ requires C, 73·9; H, 5·2; OMe, 9·6%).

7-o-Chlorophenylperinaphthan-1-one (VIII).—A mixture of the above carbinol (1 g.) and iodine (10 mg.) in light petroleum (b. p. 80—100°) was heated under reflux for ½ hour. The cooled solution was washed with dilute sodium thiosulphate and then with water and evaporated. Crystallisation from

ethanol gave 7-o-*chlorophenylperinaphthan*-1-*one* (0·7 g.) as pale yellow prisms, m. p. 109—110° (Found : C, 77·6; H, 4·5; OMe, 0·0. $C_{19}H_{13}OCl$ requires C, 77·9; H, 4·4; OMe, 0·0%). The same ketone was obtained in quantitative yield when the carbinol (0·5 g.) in methanol (5 c.c.) and benzene (1 c.c.) was treated with a saturated solution of methanolic hydrogen chloride (1 c.c.), for 24 hours. The 2 : 4-*dinitrophenylhydrazone* formed soft deep-red needles, m. p. 228° (decomp.), from glacial acetic acid (Found: C, 63·2; H, 3·7 $C_{25}H_{17}O_4N_4Cl$ requires C, 63·5; H, 3·6%). The *semicarbazone* crystallised from ethanol in clusters of bright yellow needles which sintered at 220° and finally melted with decomposition at 236° (Found : C, 68·9; H, 4·8. $C_{20}H_{16}ON_3Cl$ requires C, 69·2; H, 4·6%). The *benzylidene* derivative crystallised out when a mixture of the ketone (0·3 g.), benzaldehyde (1 g.), potassium hydroxide (1 g.), and ethanol (15 c.c.) was set aside for 24 hours at room temperature. After recrystallisation from xylene, it formed bright yellow prisms, m. p. 225° (Found: C, 81·9; H, 4·7. $C_{26}H_{17}OCl$ requires C, 81·9; H, 4·5%).

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