701. *Friedel–Crafts Acetylation of Chrysene.*

By W. Carruthers.

Reaction of chrysene with acetyl chloride and aluminium chloride in carbon disulphide–acetyl chloride or in nitrobenzene yields a mixture of 2-, 4-, and 5-acetylchrysenes. In methylene chloride only 2-acetylchrysene is produced. 2-, 4-, and 5-Ethylchrysenes are readily obtained by reduction of the corresponding acetyl compounds.

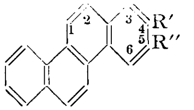
Although several methods have been elaborated for the synthesis of alkylchrysenes (see, for example, Newman, *J. Amer. Chem. Soc.*, 1938, **60**, 2947; 1940, **62**, 870; Bachmann and Struve, *J. Org. Chem.*, 1939, **4**, 456; 1940, **5**, 416), all are laborious. A more direct route to some at least of these compounds would be afforded by reduction of the ketones known to be produced by Friedel–Crafts acylation of chrysene. The orientation of these ketones, however, is not securely established, and the present investigation was designed to identify the acetylation products of chrysene.

Reaction of chrysene with acetyl chloride and aluminium chloride in a mixture of carbon disulphide and acetyl chloride was studied by Funke and Müller (*J. pr. Chem.*, 1936, **144**, 242), who isolated two ketones which they regarded as 1- and 2-acetylchrysenes. Newman (*loc. cit.*), however, showed that the alleged 1-isomer could not in fact have this orientation, for the ethylchrysene obtained from it by reduction was different from 1-ethylchrysene which he synthesised by an unambiguous route. It was suggested by Bergmann and Eschinazi (*J. Amer. Chem. Soc.*, 1943, **65**, 1413) that this ketone was actually 4-acetylchrysene, on the basis of its high melting-point.

In the present work, reaction in a mixture of carbon disulphide and acetyl chloride as described by Funke and Müller (*loc. cit.*) gave three ketonic products, isolated by fractional crystallisation. Two of these were identical with the compounds found by Funke and Müller (*loc. cit.*); the third was apparently overlooked by these authors. 2-Acetylchrysene was identified by Clemmensen reduction to the known 2-ethylchrysene and by oxidation to the known 2-carboxylic acid. The so-called " 1-acetylchrysene " was shown to be 4-acetylchrysene, since on Clemmensen reduction it afforded 4-ethylchrysene which was identified through its unequivocal synthesis as described below. Because of its low solubility, this isomer was readily isolated from the reaction mixture in about 15% yield. The third isomer, obtained in approximately 10% yield, was identified as 5-acetylchrysene by reduction to 5-ethylchrysene, which was also synthesised. A similar mixture of the 2-, 4-, and 5-isomers was obtained when the reaction was conducted in nitrobenzene solution. In methylene chloride, however, only 2-acetylchrysene was produced, in high yield (75%). This is fortunate, for the 2-isomer is the most difficult to isolate from the reactions in nitrobenzene and carbon disulphide.

Chrysene thus resembles phenanthrene (Mosettig and van de Kamp, *J. Amer. Chem. Soc.*, 1930, **52**, 3704) in reacting to a considerable extent in a side ring during Friedel–Crafts acetylation in nitrobenzene and carbon disulphide. This is in accord with Baddeley's observation (*J.*, 1949, S 1, 99) that use of nitrobenzene as solvent in acetylation of naphthalene leads to greater reaction at the less reactive, but sterically less hindered, β-position, than occurs in methylene chloride.

The starting material for the synthesis of 4-ethylchrysene was 2-ethyl-9 : 10-dihydrophenanthrene (II), itself obtained from the corresponding acetyl compound (Burger and Mosettig, *J. Amer. Chem. Soc.*, 1936, **58**, 1857) by Huang-Minlon reduction (*J. Amer. Chem. Soc.*, 1946, **68**, 2487). Condensation of (II) with succinic anhydride and aluminium chloride in nitrobenzene afforded a keto-acid which, by analogy with the similar reaction of 9 : 10-dihydrophenanthrene (Burger and Mosettig, *J. Amer. Chem. Soc.*, 1937, **59**, 1302), is regarded as (III). Reduction of this by the Huang-Minlon procedure (*loc. cit.*) yielded the corresponding butyric acid, the methyl ester of which was dehydrogenated by heating it with palladium. The product was hydrolysed, and the resulting ethylphenanthrylbutyric acid (IV) cyclised by treatment of its acid chloride with stannic chloride, yielding 10-ethyl-3 : 4 : 5 : 6-tetrahydro-6-oxochrysene (V) almost exclusively (compare Bachmann and Struve, *J. Org. Chem.*, 1939, **4**, 456). Clemmensen reduction of the carbonyl group, followed by dehydrogenation of the crude product with palladium, gave 4-ethylchrysene (I; R′ = Et, R″ = H).



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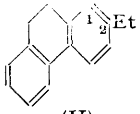

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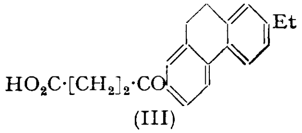

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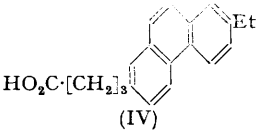

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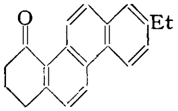

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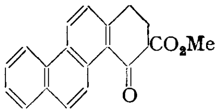

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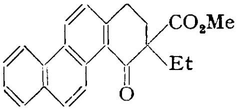

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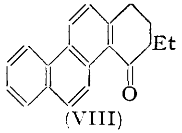

(VIII)

5-Ethylchrysene was prepared from methyl 3 : 4 : 5 : 6-tetrahydro-6-oxochrysene-5-carboxylate (VI) (Bachmann and Struve, *J. Org. Chem.*, 1940, **5**, 416). Reaction of this compound with ethyl iodide in the presence of sodium methoxide furnished the expected product (VII) and hence, by boiling it with hydrochloric acid, the ketone (VIII). 5-Ethylchrysene was readily obtained from this ketone by Clemmensen reduction, and dehydrogenation of the resultant crude tetrahydrochrysene derivative with palladium.

EXPERIMENTAL

Acetylation of Chrysene.—(a) *In carbon disulphide.* Acetyl chloride (60 c.c.) and powdered aluminium chloride (10 g.) were added to a stirred suspension of finely powdered chrysene (10 g.) in carbon disulphide (250 c.c.). After 2 days the mixture was boiled for 6 hr. The solvent was removed, and ice and hydrochloric acid were added. The dried residue was boiled with carbon tetrachloride (250 c.c.) and filtered hot. The crystals which separated on cooling were combined with the residue, and the whole crystallised from benzene–ethanol (charcoal), whereby 4-*acetylchrysene* (1·6 g.) was obtained as needles, m. p. 252—253° (Found: C, 88·7; H, 5·5. $C_{20}H_{14}O$ requires C, 88·8; H, 5·2%). The carbon tetrachloride solution was concentrated to 50 c.c., separated from a little 4-acetylchrysene, and set aside at 0° for several days. The crystals were collected and crystallised from benzene–light petroleum (b. p. 60—80°), yielding 5-*acetylchrysene* (1·0 g.) as needles, m. p. 159° (Found: C, 89·1; H, 5·4%). Further concentration of the mother liquors, and fractional crystallisation of the material obtained from carbon tetrachloride and from ethanol yielded 2-acetylchrysene (0·5 g.), m. p. 141° (lit. 144°), and a further small amount of 5-acetylchrysene.

(b) *In nitrobenzene.* Aluminium chloride (3·4 g.) and acetyl chloride (1·8 c.c.) were dissolved in nitrobenzene (15 c.c.), and to the stirred solution, at 0°, was added a suspension of finely powdered chrysene (5 g.) in nitrobenzene (35 c.c.). After 1 hr. the temperature was raised to 35—40°, and stirring continued for 4 hr. Next morning, ice and hydrochloric acid were added and nitrobenzene removed in steam. The washed and dried crude product (5·8 g.) was extracted with boiling ethanol (4 × 40 c.c.), and the combined extracts set aside. The crystals (1·7 g.) which separated were combined with the residue and crystallised from benzene (charcoal), giving 4-acetylchrysene (0·7 g.) as needles, m. p. 254°. The alcohol liquors were evaporated and the residue crystallised from carbon tetrachloride as described above, yielding 2- and 5-acetylchrysene, in yields of 0·6 g. and 0·5 g., respectively.

(c) *In methylene chloride.* A suspension of finely powdered chrysene (5 g.) in methylene chloride (25 c.c.) was added to a stirred solution of aluminium chloride (3·4 g.) and acetyl chloride (1·8 c.c.) in methylene chloride (100 c.c.) at 0°. Stirring was continued for a further 2 hr. at 35—40°. Next morning, ice and hydrochloric acid were added, and methylene chloride was distilled off. The crude product (5·7 g.), after being washed and dried, was adsorbed in benzene on alumina. Elution with benzene first removed a small amount of chrysene. 2-Acetylchrysene was then obtained and after crystallisation from benzene–ethanol formed needles (3·9 g.), m. p. 142—143°. No other product was detected.

Oxidation of 2-, 4-, *and* 5-*Acetylchrysenes.*—The acetylchrysenes were oxidised to the carboxylic acids with sodium hypoiodite, by the method described by Fuson and Tulloch (*J. Amer. Chem. Soc.*, 1934, **56**, 1638). *Chrysene*-4-*carboxylic acid* formed clusters of fluffy pale yellow needles, m. p. 325—327° (decomp.), from dioxan (Found: C, 83·6; H, 4·6. $C_{19}H_{12}O_2$ requires C, 83·8; H, 4·4%). The *methyl* ester, from the acid and diazomethane, crystallised from benzene in pale yellow plates, m. p. 219° (Found: C, 83·7; H, 4·9. $C_{20}H_{14}O_2$ requires C, 83·9; H, 4·9%). *Chrysene*-5-*carboxylic acid* was obtained from aqueous dioxan as pale yellow needles, m. p. 295° (decomp. with sintering at 285°) (Found: C, 84·1; H, 4·6%). Treatment of the acid with diazomethane afforded the *methyl* ester as plates, m. p. 146—147° (Found: C, 83·7; H, 4·7%). Chrysene-2-carboxylic acid gave pale yellow needles, m. p. 305° (decomp.), from dioxan (Funke and Müller, *loc. cit.*, give m. p. 308°). The *methyl* ester formed plates, m. p. 143—144°, from methanol–benzene (Found: C, 83·6; H, 4·9%).

2-*Ethyl*-9 : 10-*dihydrophenanthrene* (II).—2-Acetyl-9 : 10-dihydrophenanthrene (1·3 g.), potassium hydroxide (0·8 g.), and hydrazine hydrate (90%; 1 c.c.) in diethylene glycol (9 c.c.) were boiled for 1 hr. The temperature was then raised to 190—200° by distilling off the water, and refluxing continued for 3 hr. further. The cooled mixture was diluted with water, acidified, and extracted with benzene. The washed and dried extract was evaporated and the residual oil distilled over sodium. 2-*Ethyl*-9 : 10-*dihydrophenanthrene* was collected as a colourless oil (1·1 g.), b. p. 130°/0·4 mm. (Found: C, 92·4; H, 7·5. $C_{16}H_{16}$ requires C, 92·3; H, 7·7%).

Reaction of 2-*Ethyl*-9 : 10-*dihydrophenanthrene with Succinic Anhydride.*—To an ice-cold solution of the above hydrocarbon (1·4 g.) and succinic anhydride (0·7 g.) in nitrobenzene (3 c.c.) was added a suspension of powdered aluminium chloride (1·8 g.) in nitrobenzene (5 c.c.). The mixture was allowed to warm to room temperature overnight and decomposed with ice and hydrochloric acid. Nitrobenzene was removed in steam, and the residue extracted with sodium carbonate solution. Acidification yielded a brown powder (1·7 g.); after crystallisation from acetic acid and from benzene–light petroleum (b. p. 60—80°), β-(7-*ethyl*-9 : 10-*dihydro*-2-*phenanthroyl*)*propionic acid* (III) formed blades, m. p. 163—164° (Found: C, 78·2; H, 6·6. $C_{20}H_{20}O_3$ requires C, 77·9; H, 6·5%).

γ-(7-*Ethyl*-9 : 10-*dihydro*-2-*phenanthryl*)*butyric Acid.*—A solution of the keto-acid (1·0 g.), sodium hydroxide (0·5 g.), and hydrazine hydrate (90%; 1 c.c.) in diethylene glycol (10 c.c.) was refluxed for 1 hr. The temperature of the solution was then raised to 190—200° by distilling off some of the water, and refluxing continued for 3 hr. more. The cooled solution was diluted with water, acidified, and extracted with benzene. The *acid* (0·95 g.) was obtained on evaporation of the solvent; it crystallised from aqueous ethanol in plates, m. p. 122—123° (Found: C, 81·5; H, 7·3. $C_{20}H_{22}O_2$ requires C, 81·6; H, 7·5%).

γ-(7-*Ethyl*-2-*phenanthryl*)*butyric Acid* (IV).—The dihydrophenanthrylbutyric acid (0·6 g.) was converted into its methyl ester by treatment with diazomethane. The crude ester was dehydrogenated directly by heating it at 260—270° with palladium–charcoal (10%; 0·4 g.) in carbon dioxide. The product was extracted with benzene and hydrolysed with aqueous-alcoholic potassium hydroxide. The crude acid obtained on acidification (0·48 g.) was crystallised from dilute acetic acid and from benzene–*n*-hexane, yielding γ-(7-*ethyl*-2-*phenanthryl*)-*butyric acid* (0·2 g.) as plates, m. p. 172—173° (Found: C, 81·9; H, 7·0. $C_{20}H_{20}O_2$ requires C, 82·2; H, 6·9%).

10-*Ethyl*-3 : 4 : 5 : 6-*tetrahydro*-6-*oxochrysene* (V).—A suspension of γ-(7-ethyl-2-phenanthryl)-butyric acid (0·2 g.) in ether (5 c.c.) was treated with thionyl chloride (0·4 c.c.) and a few drops of pyridine. After 2 hr., ether and excess of thionyl chloride were removed, and the acid chloride was dissolved in benzene (5 c.c.). To this ice-cold solution was added, with shaking, a solution of stannic chloride (0·3 c.c.) in benzene (1 c.c.). The solution was allowed to warm to room temperature during 3 hr., and ice and hydrochloric acid were added. The benzene layer was separated, washed, dried, and passed through alumina. Development with benzene afforded a main orange band which yielded crystals (140 mg.); crystallisation from ethanol afforded 10-*ethyl*-3 : 4 : 5 : 6-*tetrahydro*-6-*oxochrysene* as plates, m. p. 138—139° (Found: C, 87·3; H, 6·4. $C_{20}H_{18}O$ requires C, 87·6; H, 6·6%).

4-*Ethylchrysene* (I; R′ = Et, R″ = H).—(*a*) A mixture of the above ketone (200 mg.), amalgamated zinc (1 g.), concentrated hydrochloric acid (5 c.c.), water (1 c.c.), acetic acid (2 c.c.), and toluene (1·5 c.c.) was boiled for 48 hr., the cooled mixture extracted with benzene, and the extract washed, dried, and evaporated. The solid was dehydrogenated at 280—300° for 30 min. with palladium–charcoal (30%; 200 mg.) in carbon dioxide. The product was extracted with benzene and, after purification by chromatography, gave 4-*ethylchrysene* as plates (140 mg.), m. p. 237—238° (from benzene) (Found: C, 93·5; H, 6·5. $C_{20}H_{16}$ requires C, 93·7; H, 6·3%). The 2 : 7-dinitroanthraquinone *complex* formed fluffy bright-red needles, m. p. 238° from benzene (Found: N, 5·1. $C_{34}H_{22}O_6N_2$ requires N, 5·1%).

(*b*) 4-Acetylchrysene (100 mg.), amalgamated zinc (2 g.), hydrochloric acid (10 c.c.), water (5 c.c.), acetic acid (2 c.c.), and toluene (2 c.c.) were boiled for 24 hr. The product was obtained in the usual manner, and purified by chromatography on alumina in benzene. Crystallisation from benzene–ethanol gave 4-ethylchrysene (60 mg.), m. p. 236—237° alone or mixed with the material obtained as above.

Methyl 5-*Ethyl*-3 : 4 : 5 : 6-*tetrahydro*-6-*oxochrysene*-5-*carboxylate* (VII).—Methyl 3 : 4 : 5 : 6-tetrahydro-6-oxochrysene-5-carboxylate (140 mg.) (Bachmann and Struve, *loc. cit.*) in benzene (3 c.c.) was added to a solution of sodium methoxide [from sodium (45 mg.) and methanol (1·5 c.c.)], and the solution boiled for 2 hr. Ethyl iodide (0·5 c.c.) was added and boiling continued for 30 min., followed by addition of more ethyl iodide (1 c.c.). Next morning the product was obtained as a yellow gum (158 mg.) by acidification with dilute acetic acid and extraction with benzene. It was purified by chromatography in benzene solution on silica gel, and then afforded the *keto-ester* as needles, m. p 74° (from methanol) (Found: C, 79·2; H, 5·9. $C_{22}H_{20}O_3$ requires C, 79·5; H, 6·1%).

5-*Ethyl*-3 : 4 : 5 : 6-*tetrahydro*-6-*oxochrysene* (VIII).—A mixture of the keto-ester (110 mg.), acetic acid (3 c.c.), and concentrated hydrochloric acid (1 c.c.) was boiled for 4 hr., and the cooled mixture was then diluted with water and extracted with benzene. Evaporation of the washed and dried extract yielded a gum which was chromatographed in benzene on alumina. 5-*Ethyl*-3 : 4 : 5 : 6-*tetrahydro*-6-*oxochrysene* was obtained as prisms (98 mg.), m. p. 62—63° (from hexane) (Found: C, 87·5; H, 6·4. $C_{20}H_{18}O$ requires C, 87·5; H, 6·6%).

5-*Ethylchrysene* (I; R′ = H, R″ = Et).—(*a*) A mixture of the above ketone (82 mg.), amalgamated zinc (1 g.), concentrated hydrochloric acid (4 c.c.), acetic acid (1 c.c.), and xylene (1 c.c.) was boiled for 20 hr. The product was extracted with benzene and recovered from the washed and dried extract as a brown gum (80 mg.) which was dehydrogenated with palladium–charcoal (30%; 60 mg.) at 280—300° for 30 min. in an atmosphere of carbon dioxide. The cooled mixture was extracted with benzene and the dark product (35 mg.) adsorbed on alumina. Elution with benzene afforded a nearly colourless zone from which 5-*ethylchrysene*, plates, m. p. 113—114° (10 mg.) (from ethanol), was obtained (Found: C, 93·6; H, 6·2. $C_{20}H_{16}$ requires C, 93·7; H, 6·3%). The *s*-trinitrobenzene *complex* formed yellow needles, m. p. 145—146° (Found: N, 9·2. $C_{26}H_{19}O_6N_3$ requires N, 8·95%).

(*b*) 5-Acetylchrysene (50 mg.) was reduced by the Clemmensen method as described above for the 4-isomer. The product was chromatographed in light petroleum (b. p. 60—80°) on alumina and crystallised from ethanol, yielding plates (30 mg.), m. p. 113—114° alone or mixed with the product obtained as above. Identity was confirmed by comparison of the *s*-trinitrobenzene complexes.

2-*Ethylchrysene*.—2-Acetylchrysene was reduced in the manner described above for 4-acetylchrysene. The product was purified by chromatography in benzene solution on alumina. Crystallisation from ethanol afforded 2-ethylchrysene in needles, m. p. 124—125° (lit. 124—125°).

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