The Orientation of Disubstituted Fluoranthene Derivatives.

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It is shown that 4-carboxy-, 4-methoxycarbonyl-, 4-cyano-, and 4-nitrofluoranthene are brominated in the 12-position and that sulphonation of fluoranthene gives fluoranthene-4 : 12-disulphonic acid. The theoretical implications of these results are discussed.

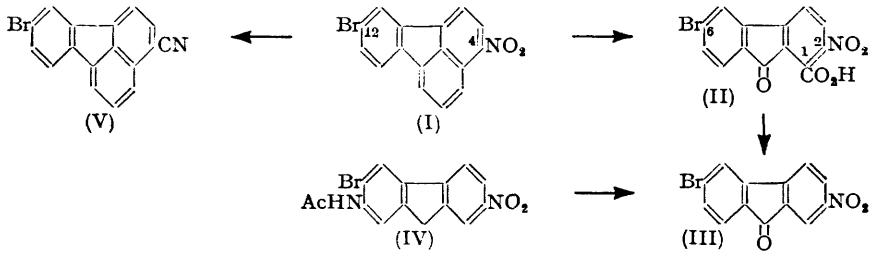
4-BROMOFLUORANTHENE, on further bromination, yields 4 : 11-dibromofluoranthene (Campbell, Easton, Rayment, and Wilshire, *J.*, 1950, 2784; Campbell, Stafford, and Wilshire, *J.*, 1951, 1137; Holbro and Tagmann, *Helv. Chim. Acta*, 1950, **33**, 2178). On the other hand 4-acetylfluoranthene on acetylation yields 4 : 12-diacetylfluoranthene (Campbell, Leadill, and Wilshire, *J.*, 1951, 1404). These are the only disubstituted fluoranthenes which have been rigidly orientated, but it has been suggested that the disulphonic acid obtained by the sulphonation of fluoranthene is the 4 : 11-compound (Tobler, Holbro, Sutter, and Kern, *Helv. Chim. Acta*, 1941, **24**, 100E). It was therefore desirable to orientate other disubstituted fluoranthenes: we have established the structures of five such. The structural proof is rigorous except for the disulphonic acid.

Bromination of 4-nitrofluoranthene in nitrobenzene affords 12-bromo-4-nitrofluoranthene (I) since when reduced, diazotised, and treated with cuprous bromide the latter yields 4 : 12-dibromofluoranthene identical with a sample prepared from 4 : 12-diacetylfluoranthene.

Oxidation of the bromonitrofluoranthene gives 6-bromo-2-nitrofluorenone-1-carboxylic acid (II), which when heated in quinoline yields 2-nitrofluorenone. This loss of bromine in the 6-position is not surprising, since the lability of bromine in the 3-position of fluorenone has been reported (Montagne, *Rec. Trav. chim.*, 1909, **28**, 449). Decarboxylation in pyridine, however, affords 6-bromo-2-nitrofluorenone (III) which was synthesised by brominating 2-acetamido-7-nitrofluorene to give the 3-bromo-derivative (IV). Hydrolysis followed by removal of the amino-group yields 6-bromo-2-nitrofluorene, which is oxidised to 6-bromo-2-nitrofluorenone (III) identical with the substance prepared above. This

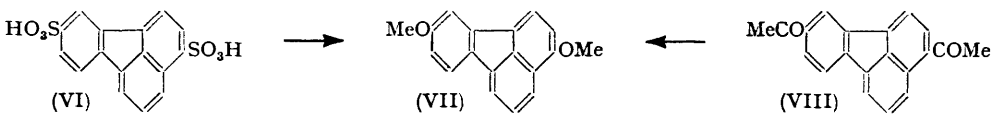
series of reactions incidentally proves that bromination of 2-acetamido-7-nitrofluorene occurs at the 3- and not at the 1-position (cf. Bell and Mulholland, *J.*, 1949, 2020).

4-Cyanofluoranthene is likewise brominated in the 12-position since the product (V) was identical with 12-bromo-4-cyanofluoranthene obtained from 4-amino-12-bromofluoranthene. The cyano-compound was converted into 12-bromofluoranthene-4-carboxylic acid and its methyl ester, which were required as reference compounds. They were



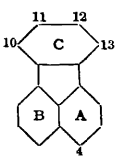
found to be identical with the bromination products of fluoranthene-4-carboxylic acid and its methyl ester, thus showing that substitution had again occurred in the 12-position. The bromination of 4-acetylfluoranthene was attempted, but no pure product was isolated.

Of interest is the orientation of the disulphonic acid obtained by the direct sulphonation of fluoranthene (Goldschmiedt, *Monatsh.*, 1880, **1**, 221; von Braun and Manz, *Annalen*, 1931, **488**, 111; G.P. 575,953) which it has been suggested is the 4 : 11-compound on account of the quinhydrone-type product obtained by fusion with alkali (Tobler *et al.*, *loc. cit.*). Since monosulphonation occurs mainly in the 4-position the disulphonic acid must contain one sulpho-group in that position, and by analogy with the effect of other *m*-directing groups discussed above it is to be expected that the second sulpho-group will occupy the 12-position. Many unsuccessful attempts were made to convert the disulphonic acid into known reference compounds. Success was achieved by fusing the acid with potassium hydroxide to give a dihydroxy-compound, methylation of which yielded a product identical with a specimen prepared from 4 : 12-diacetylfluoranthene (VIII) (Camp-



bell, Leadill, and Wilshire, *loc. cit.*). This diacetylfluoranthene was oxidised by perbenzoic acid (Friess *et al.*, *J. Amer. Chem. Soc.*, 1949, **71**, 14; 1950, **72**, 5518; 1951, **73**, 3968). The diacetate thus formed was hydrolysed and with diazomethane then gave 4 : 12-dimethoxyfluoranthene identical with the compound mentioned above. Unless therefore the fusion of the sulphonic acid with alkali has been accompanied by the migration of one or both sulpho-groups the acid is indeed fluoranthene-4 : 12-disulphonic acid (VI).

From the results so far obtained it appears that 4-substituted fluoranthenes undergo further substitution mainly in the 11- or the 12-position according to whether the first substituent is *ortho-para*- or *meta*-directing. In harmony with this is the observation that 4-azafluoranthene gives a 12-nitro-derivative (Koelsch and Steinhauer, *J. Org. Chem.*, 1953, **18**, 1516). A possible explanation of these results may be found by considering



fluoranthene as a diphenyl derivative containing the diphenyl nuclei AC and BC. Now it is established in the diphenyl series that " constancy of type of substitution prevails," *i.e.*, orientation is dominated by the phenyl groups (Waters, *Chem. Rev.*, 1930, **7**, 421; Le Fèvre and Turner, *J.*, 1928, 245; Blakey and Scarborough, *J.*, 1928, 3000; Vorländer, *Ber.*, 1925, **58**, 1893). To be more specific, substitution in most cases occurs in the second ring in the 2'- and 4'-positions irrespective of the nature and position of the substituent already present in the first ring. The three nitrodiphenyls, for example, undergo substitution in the 2'- and 4'-positions, but not in the 3'(" meta ")-position. The same regularities are observed in the fluorene molecule. Applying this to fluoranthene it is reasonable to postulate that in (I) each of the

rings A and B directs substituents predominantly to the "*para*"-position in ring C, *i.e.*, to positions 11 and 12 respectively, and (2) an *ortho-para*-directing group in ring A increases the directive power of this ring with consequent substitution at $C_{(11)}$ (and possibly $C_{(13)}$), while *meta*-directing groups decrease the directive power of ring A so that ring B dominates further substitution, which therefore occurs at $C_{(12)}$ (and possibly $C_{(10)}$).

Experimental

12-*Bromo*-4-*nitrofluoranthene*.—Bromine (0·85 ml.) in nitrobenzene (1 ml.) was added dropwise at room temperature to 4-nitrofluoranthene (2 g.) in nitrobenzene (20 ml.) and the solution was stirred for 2 hr. The precipitate was dissolved in chlorobenzene, and the solution washed with aqueous sodium hydroxide and then with water. The volume of the dried (Na_2SO_4) solution was reduced and **12-*bromo*-4-*nitrofluoranthene*** (48%) separated and crystallised from chlorobenzene in orange-yellow needles, m. p. 216—218° (Found: N, 4·4; Br, 24·7. $C_{16}H_8O_2NBr$ requires N, 4·3; Br, 24·5%). The bromonitro-compound (1 g.) was boiled in ethanol (100 ml.) with iron powder (1 g.) and concentrated hydrochloric acid (10 ml.) for 4 hr., during which hydrochloric acid (5 ml.) and iron powder (0·5 g.) were added. The mixture was made alkaline with ammonia, poured into water, and extracted with chloroform. The extract with a little concentrated hydrochloric acid gave the amine hydrochloride, which with ammonia yielded **4-*amino*-12-*bromofluoranthene*** (73%), yellow needles [from light petroleum (b. p. 60—80°)], m. p. 161—163° (Found: C, 64·6; H, 3·3; N, 4·2. $C_{16}H_{10}NBr$ requires C, 64·9; H, 3·4; N, 4·7%).

The bromo-amine (0·6 g.) in acetic acid (5 ml.) was added slowly to a stirred solution of sodium nitrite (1 g.) in concentrated sulphuric acid (7 ml.) and after 1 hour's stirring the solution was poured into a boiling solution of freshly prepared cuprous bromide (1 g.) in 34% hydrobromic acid. The mixture was poured into water and extracted with benzene. The insoluble residue was boiled with benzene and the combined extracts were washed with water, dried (Na_2SO_4), and chromatographed on alumina. A buff-coloured band separated and on extraction with benzene yielded a solid which was chromatographed. A yellow band separated and yielded 4 : 12-dibromofluoranthene, yellow needles (from benzene–light petroleum), m. p. and mixed m. p. 165—168°.

Oxidation of **12-*Bromo*-4-*nitrofluoranthene*.**—Chromic acid (2 g.) in water (12 ml.) and acetic acid (8 ml.) was added to a cold stirred solution of the bromonitrofluoranthene (1 g.) in acetic acid (100 ml.), and the mixture stirred overnight. It was boiled (½ hr.) and half the solvent removed by distillation. The solution was poured into water and extracted with ether. The ether layer was extracted with aqueous sodium carbonate and the carbonate extract on acidification with hydrochloric acid gave **6-*bromo*-2-*nitrofluorenone*-1-*carboxylic acid*** (28%), yellow needles (from acetic acid), m. p. 260—266° (decomp.) (Found: N, 3·9; Br, 23·5. $C_{14}H_6O_5NBr$ requires N, 4·0; Br, 23·0%). The acid when heated in quinoline for 15 min. at 220° afforded 2-nitrofluorenone, m. p. and mixed m. p. 220°. The acid (0·09 g.) was boiled with a trace of copper bronze in pyridine for ½ hr. and poured into dilute hydrochloric acid. The suspension was extracted with benzene, and the benzene extract washed with sodium carbonate solution, then water, and dried (Na_2SO_4). Evaporation of the solvent gave 6-bromo-2-nitrofluorenone (15%), yellow needles (from acetic acid–methanol), m. p. 272—274° (Found: N, 4·7; Br, 24·9. Calc. for $C_{13}H_6O_3NBr$: N, 4·6; Br, 26·3%). The decarboxylation was evidently accompanied by a little debromination.

Synthesis of **6-*Bromo*-2-*nitrofluorenone*.**—It is reported that 2 : 7-dinitrofluorene is quantitatively reduced to the aminonitro-compound by bubbling hydrogen sulphide through a suspension of the compound in hot ammoniacal ethanol (Cislak and Hamilton, *J., Amer. Chem. Soc.*, 1931, **53**, 746). We found it essential to boil the ethanolic suspension of the pulverised dinitrofluorene before reduction and to use an extremely vigorous stream of hydrogen sulphide. This gave a 66% yield of the product. A quantitative yield was obtained only by reprocessing unchanged starting material.

2-Acetamido-7-nitrofluorenone (2 g.) was added slowly to bromine (20 ml.) in carbon tetrachloride (20 ml.), and the mixture was boiled for ½ hr., the volume being kept constant by addition of solvent. The cold mixture was washed with aqueous sodium hydroxide and then poured into chlorobenzene The carbon tetrachloride was boiled off and the residual chlorobenzene solution was washed with aqueous sodium hydroxide and then water. The dried solution (Na_2SO_4) was reduced in volume and **2-*acetamido*-3-*bromo*-7-*nitrofluorene*** (39%) separated and crystallised from xylene in yellow needles, m. p. 283—287° (Found: N, 7·9; Br, 22·6. $C_{15}H_{11}O_3N_2Br$ requires N, 8·1; Br, 23·0%). The acetamido-compound (1 g.) was

boiled for 4 hr. in ethanol (150 ml.) and concentrated hydrochloric acid (25 ml.), more acid (5 ml.) being added after 2 hr. The mixture was made alkaline with concentrated ammonia solution and poured into water. An orange precipitate of 2-amino-3-bromo-7-nitrofluorene (97%) separated. The amine (0·35 g.) in boiling acetic acid (5 ml.) was chilled rapidly and the suspension was slowly added to a stirred solution of sodium nitrite (1 g.) in concentrated sulphuric acid (7 ml.) at 20°. The mixture was stirred (1 hr.). Ethanol (10 ml.) and copper bronze (trace) were added and the mixture was gently heated until the temperature reached 80°. It was then poured into water and the aqueous suspension extracted with benzene. The extract was washed with water, dried (Na_2SO_4), and chromatographed. From the eluate *6-bromo-2-nitrofluorene* (19%), colourless needles (from acetic acid–ethanol), m. p. 207°, was obtained (Found: N, 5·2; Br, 28·1. $C_{13}H_8O_2NBr$ requires N, 4·8; Br, 27·6%). Sodium dichromate (0·18 g.) in water (0·5 ml.) and acetic acid (1·5 ml.) was slowly added to the bromonitrofluorene (0·06 g.) in boiling acetic acid (1·5 ml.). The mixture was boiled (1 hr.) and poured into ice-water. *6-Bromo-2-nitrofluorenone* (19%) separated as yellow needles (from acetic acid–ethanol), m. p. 272—274° (Found: N, 4·9; Br, 26·6%). When admixed with the bromonitrofluorenone prepared as above it gave no m. p. depression.

12-Bromo-4-cyanofluoranthene.—4-Amino-12-bromofluoranthene (1 g.) in acetic acid (12 ml.) was added slowly to a stirred solution of sodium nitrite (1 g.) in concentrated sulphuric acid (7 ml.) at 10°. The mixture was stirred (½ hr.) and poured into an aqueous solution of cuprous cyanide and potassium cyanide at 60°. The mixture was boiled (¼ hr.) and poured into water and extracted with benzene. The benzene extract was washed with water, dried (Na_2SO_4) and chromatographed. The column gave a yellow zone which was extracted and on evaporation yielded 12-bromo-4-cyanofluoranthene, yellow needles (from ethanol), m. p. 222—224°, identical with the substance prepared from 4-cyanofluoranthene.

4-Cyanofluoranthene.—The following method for the preparation of this compound was found to be more satisfactory than that of von Braun and Manz (*Annalen*, 1931, **488**, 111). 4-Bromofluoranthene (4·1 g.), freshly prepared cuprous cyanide (4·1 g.), pyridine (40 ml.), and benzyl cyanide (5 drops) were heated at 240° in a sealed-tube for 24 hr. The product was boiled with benzene and the cold mixture filtered. The precipitate was washed with dilute hydrochloric acid, followed by water, and was shown to be 4-carbamoylfluoranthene, colourless needles, m. p. 278—280° (Found: C, 84·3; H, 4·8; N, 5·9. Calc. for $C_{17}H_{11}ON$: C, 83·3; H, 4·5; N, 5·7%). It was previously described as a golden-brown substance, m. p. 271—273° (von Braun and Manz, *loc. cit.*). The original benzene filtrate was reduced to a small volume and chromatographed on alumina. Development with benzene gave a yellow band which on elution and evaporation gave 4-cyanofluoranthene (64%), m. p. 114—115°.

Bromination of 4-Cyanofluoranthene.—Bromine (0·23 ml.) in nitrobenzene (1 ml.) was added slowly to a stirred solution of 4-cyanofluoranthene (0·5 g.) in nitrobenzene (1 ml.). After 2 hr. the precipitate was filtered off, washed successively with benzene, sodium hydroxide solution, and water, and finally chromatographed on alumina with benzene as solvent and developer. Elution of a yellow zone yielded *12-bromo-4-cyanofluoranthene* (66%), yellow needles (from benzene–light petroleum), m. p. 222—225°, showing no depression when admixed with a sample prepared as above (Found: N, 4·6; Br, 26·6. $C_{17}H_8NBr$ requires N, 4·6; Br, 26·1%).

12-Bromofluoranthene-1-carboxylic Acid.—12-Bromo-4-cyanofluoranthene (0·65 g.), sodium hydroxide (0·5 g.), water (1·5 ml.), and ethylene glycol (10 ml.) were boiled (5 hr.), then poured into water, and the mixture was acidified and extracted with benzene. The benzene solution was shaken with sodium carbonate solution, and the carbonate extract on acidification gave a precipitate of crude acid. The acid (0·4 g.) was boiled in methanol (100 ml.) and concentrated sulphuric acid (3 ml.) for 18 hr. and poured into water. The precipitate was dissolved in benzene and the solution after being washed with sodium carbonate and water was chromatographed on alumina. Development with benzene gave one main yellow band which on elution yielded *methyl 12-bromofluoranthene-1-carboxylate*, yellow needles (from methanol), m. p. 171—173° (Found: Br, 22·6. $C_{18}H_{11}O_2Br$ requires Br, 23·6%). The ester (0·1 g.) was boiled for 12 hr. with sodium hydroxide (0·5 g.), methanol (10 ml.), and water (5 ml.) and on acidification yielded *12-bromofluoranthene-4-carboxylic acid*, yellow needles (from acetic acid or benzene), m. p. 318—321° (Found: Br, 24·1. $C_{17}H_9O_2Br$ requires Br, 24·6%).

Bromination of Fluoranthene-4-carboxylic Acid and its Methyl Ester.—The acid was obtained in 78% yield by hydrolysing 4-cyanofluoranthene (0·4 g.) with water (4 ml.), sulphuric acid (4 ml.), and acetic acid (8 ml.). Bromine (0·4 ml.) was added to the acid (0·7 g.) in acetic acid (20 ml.), and carbon tetrachloride (10 ml.) stirred at 25° for 5 hr. and kept overnight. It

was stirred for a further 8 hr. and again kept overnight. 12-Bromofluoranthene-4-carboxylic acid separated and crystallised from acetic acid in yellow needles, m. p. and mixed m. p. 320—323°.

Bromine (0·2 ml.) was added to methyl fluoranthene-4-carboxylate (0·7 g.) in carbon disulphide (10 ml.) and carbon tetrachloride (10 ml.) and after being stirred at 25° for 5 hr. the mixture was kept overnight. Removal of the solvent gave methyl 12-bromofluoranthene-4-carboxylate, which after being washed with sodium carbonate solution and then with water, crystallised from benzene–ethanol and then methanol (twice) as yellow needles, m. p. and mixed m. p. 168—170°.

4-*Acetylfluoranthene*.—Magnesium (0·33 g.), absolute ethanol (1·3 ml.), and carbon tetrachloride (0·1 ml.) were gently heated and the reaction which set in was allowed to continue for several minutes. Dry ether (9 ml.) was added and diethyl malonate (2 ml.) in ethanol (1·3 g.) and ether (2 ml.) was dropped into the solution. The solution was boiled for 1 hr. and into the cooled mixture a benzene solution of fluoranthene-4-carbonyl chloride (0·3 g.) was poured carefully. The mixture was boiled for 1 hr. and kept overnight. Removal of the solvents at reduced pressure gave a viscous oil, which was boiled for 4 hr. in glacial acetic acid (3 ml.), concentrated sulphuric acid (0·4 ml.), and water (2 ml.). The solution was kept overnight, neutralised by sodium hydroxide solution, and extracted with ether. The ether extract was washed with sodium carbonate solution, followed by water, and the dried ether extract (Na_2SO_4) on evaporation yielded 4-acetylfluoranthene (40%), pale yellow needles (from alcohol), m. p. 126—129°, not depressed when admixed with an authentic sample prepared from 4-cyanofluoranthene (Campbell and Easton, *J.*, 1949, 340).

Disulphonation of Fluoranthene.—Powdered fluoranthene (20 g.) was stirred into cold concentrated sulphuric acid (40 g.) and gently warmed until it had dissolved. The mixture was poured into water and neutralised with barium carbonate. After removal of the barium sulphate, the solution of the barium fluoranthenedisulphonate was carefully acidified by dilute sulphuric acid until no more barium sulphate was precipitated. The suspension was filtered through a bed of Filter-cel, and the filtrate neutralised with potassium hydroxide solution. The solution was evaporated to dryness under reduced pressure, leaving potassium fluoranthenedisulphonate as a pale yellow solid (Found: S, 15·2. Calc. for $C_{16}H_8O_6S_2K_2$: S, 14·6%). The yield was good though the product was probably contaminated with potassium sulphate. Partition chromatography showed that sulphonation under these conditions gives mainly the disulphonic acid, together with some monosulphonic acid and a trace of unchanged fluoranthene.

4 : 12-*Dimethoxyfluoranthene*.—The potassium fluoranthenedisulphonate (21·5 g.) and potassium hydroxide (50 g.) were fused in a stream of nitrogen, and the cooled melt was dissolved in water. Acidification followed by extraction with ether gave an extract, which was dried (Na_2SO_4) and evaporated to give crude 4 : 12-dihydroxyfluoranthene (44%), which can be purified by crystallisation from light petroleum. Methyl sulphate (0·9 g.) in a little water and *tert.*-butanol was added with stirring to dihydroxyfluoranthene (1 g.), sodium hydroxide (0·4 g.), and water (10 ml.). The mixture was stirred (1 hr.), boiled (2 hr.), poured into water, and extracted with ether. The ether layer was washed with sodium hydroxide solution and then water, and the solvent exchanged for benzene. The benzene solution was chromatographed and a yellow band separated which on elution yielded 4 : 12-*dimethoxyfluoranthene* (49%), pale yellow plates, m. p. 158—159·5°, alone or when admixed with the dimethoxy-compound described below (Found: C, 82·8; H, 5·7. $C_{18}H_{14}O_2$ requires C, 82·4; H, 5·3%). Attempts to oxidise the substance to a disubstituted fluorenone-1-carboxylic acid were unsuccessful.

4 : 12-Diacetylfluoranthene (2 g.) in a 4% solution of perbenzoic acid in chloroform (100 ml.) was kept in the dark at room temperature for 10 days with occasional shaking. The solution was washed with aqueous sodium carbonate followed by water, and was dried (Na_2SO_4). Removal of the chloroform yielded the diacetate (1·04 g.), m. p. 125—130°, which was boiled with 10% sodium hydroxide (50 ml.) for 5 hr.; the mixture was filtered, acidified, and extracted with ether. The dried extract (Na_2SO_4) was treated with an ethereal solution (50 ml.) of diazomethane and kept overnight, and the ether removed. The residue in benzene was chromatographed and gave a yellow band which on elution afforded 4 : 12-dimethoxyfluoranthene, m. p. 156—157°, alone or admixed with the above dimethoxy-compound.

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