700. *Fluorine-substituted Polycyclic Compounds.*

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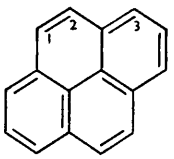
Attempts to fluorinate three polycyclic hydrocarbons with *p*-tolyliododifluoride according to the method of Garvey, Halley, and Allen [1] have been unsuccessful. Very small yields have been obtained by using modified conditions; and when chlorinated solvents were used some chlorination of the hydrocarbons resulted.

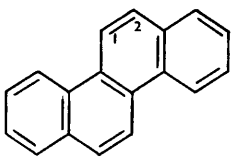
A number of fluorine-substituted polycyclic compounds has been prepared by the Schiemann reaction.

FLOURINE-SUBSTITUTED polycyclic aromatic compounds are of possible interest in experimental carcinogenesis, and it was therefore desirable to attempt the preparation of a series of such compounds by the direct substitution of the hydrocarbons, using *p*-tolyliododifluoride. This reagent was introduced by Bockemuller,[2] who found that with diethylaniline it gives *NN*-diethyl-*p*-fluoroaniline and tetra-*N*-ethylbenzidine. Garvey, Halley, and Allen [1] obtained similar results with a few aromatic hydrocarbons and ketones. For example, in chloroform, pyrene (I) was reported to give a fluoropyrene of unknown orientation, and dipyrenyl. This reaction with pyrene has now been repeated under the conditions given, but only unchanged pyrene could be recovered (Lund and Berg [3] also attempted this reaction, but without success).

It is possible that some unknown factor may be of critical significance, and a series of experiments was therefore carried out. Reaction did occur when a mixture of aqueous



(I)



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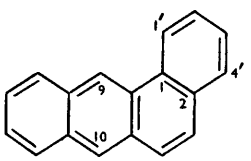

(III)

hydrofluoric acid and chloroform was used as a solvent, but in this case 3-chloropyrene was obtained together with a hydrocarbon, probably 3 : 3′-dipyrenyl. Similarly chrysene (II) was not fluorinated under the reaction conditions specified for other compounds by Garvey, Halley, and Allen; [1] but when a mixture of aqueous hydrofluoric acid and chloroform (or *s*-tetrachloroethane) was used, 2-chlorochrysene was obtained in high yield. Presumably the chlorinated solvent is first attacked by the reagent, liberating chlorine radicals, which then react with the hydrocarbon. The reaction with pyrene was certainly inhibited by the addition of quinol; and the formation of 3 : 3′-dipyrenyl is consistent with the view that a radical mechanism is involved.

A chlorine-free solvent was therefore indicated; when acetic acid was used, pyrene gave 3 : 3′-dipyrenyl together with a little of the desired 3-fluoropyrene. Similarly, 1 : 2-benzanthracene (III) gave a difluoro-1 : 2-benzanthracene, but in very small yield.

[1] Garvey, Halley, and Allen, *J. Amer. Chem. Soc.*, 1937, **59**, 1827.
[2] Bockemuller, *Ber.*, 1931, **64**, 522.
[3] Lund and Berg, *Kgl. Danske Videnskab. Selsk.*, 1946, **22**, No. 15.

In our hands, therefore, the use of *p*-tolyliodofluoride proved unsatisfactory for the preparation of fluorine-substituted polycyclic compounds in reasonable quantity, and the Schiemann [4] reaction was investigated as an alternative route. This reaction involves the conversion of an amine into the diazonium fluoroborate, which is then decomposed by pyrolysis. As a wide variety of amino-substituted compounds is available, this reaction seemed to offer reasonable scope. 3-Fluoropyrene was accordingly prepared from 3-aminopyrene by a method somewhat similar to that used by Lund and Berg,[3] and 2-fluorochrysene from 2-aminochrysene in the same manner. 4'-Amino-1 : 2-benzanthraquinone gave a black diazonium fluoroborate which, on pyrolysis, gave a tar from which only 1 : 2-benzanthraquinone could be isolated. Similarly, 9-aminoanthracene gave only anthraquinone; and 10-amino-1 : 2-benzanthracene gave a tar from which no pure product could be extracted. On the other hand, 4'-amino-1 : 2-benzanthracene was successfully converted into 4'-fluoro-1 : 2-benzanthracene in very small yield.

Experimental

3-Aminopyrene.—A filtered solution, obtained by heating hydrated sodium sulphide (175 g.), anhydrous sodium hydrogen carbonate (58 g.), and ethanol (360 c.c.), was added slowly, with stirring, to 3-nitropyrene (65 g.; Vollmann *et al.*[5]) in boiling ethanol (200 c.c.). After 2 hours' boiling the mixture was concentrated to 250 c.c. and cooled. The product was collected, washed with ethanol and then water, and recrystallised from hexane, to give 3-aminopyrene (46 g.), m. p. 115—117° (Vollmann *et al.*[5] give 117—118°).

2-Aminochrysene.—2-Nitrochrysene (53 g.) was reduced with sodium hydrogen sulphide as described above. After recrystallisation from benzene and from acetone the 2-aminochrysene had m. p. 208—209°. This method was more satisfactory than that of Newman *et al.*,[6] who give m. p. 210—211° (corr.).

10-Amino-1 : 2-benzanthracene.—This was produced by the reduction of 10-nitro-1 : 2-benzanthracene with stannous chloride according to Fieser and Creech.[7] The following procedure for the preparation of the nitro-compound is superior to that described in the literature.[8, 9]

Fuming nitric acid (11 c.c.; *d* 1·5) was added cautiously to redistilled acetic anhydride (32 c.c.) at −70°. The resulting solution was then added, together with urea nitrate (25 mg.), to a suspension of 1 : 2-benzanthracene (32 g.) in redistilled acetic anhydride (40 c.c.), also at −70°. The mixture was stirred while the temperature was allowed to come to 0°, then kept thereat for 48 hr. After being washed with acetic acid the crude 10-nitro-1 : 2-benzanthracene (21 g., 56%) had m. p. 145°, and was suitable for reduction to the amine. A further 4 g. was obtained by pouring the mother-liquors into 50% acetic acid and digesting the precipitate with dilute aqueous ammonia. Further purification of both samples by chromatography on alumina in carbon tetrachloride, followed by recrystallisation from ethanol, gave 10-nitro-1 : 2-benzanthracene, m. p. 163—164°.

Schiemann Reactions.—(i) The following procedure for 3-fluoropyrene was superior to that of Lund and Berg.[3] A solution of 3-aminopyrene (25 g.) in the minimum amount of boiling acetic acid was poured into vigorously stirred 10% hydrochloric acid (500 c.c.). The product was collected, washed with a little 10% hydrochloric acid, and suspended in water (1 l.) and 33% hydrochloric acid (30 c.c.) at 5°. Sodium nitrite (10 g.) in water (120 c.c.) was then added dropwise, during 30 min., to the vigorously stirred suspension at 4—6° (addition of ice). After a further 30 min., sodium fluoroborate (28 g.) in water (200 c.c.) was added slowly with stirring, at 5°. The mixture was warmed on the steam-bath for a few minutes until the precipitate began to coagulate, after which it was rapidly cooled and then allowed to settle at 0° for 12 hr. The resulting product was washed with ice-cold alcohol (20 c.c.) and with ice-cold ether (4 × 20 c.c.) and dried at 35—40°. This dried material was added in 3—4 g. lots, to boiling xylene (500 c.c.), the vigorous reaction being allowed to subside between each addition. The xylene was then removed and the resulting tar extracted with ether. The ethereal solution was

[4] Balz and Schiemann, *Ber.*, 1927, **60**, 1186; see also Roe, *Organic Reactions*, 1949, **5**, 193.
[5] Vollmann, Becker, Corell, and Streeck, *Annalen*, 1937, **531**, 1.
[6] Newman and Cathcart, *J. Org. Chem.*, 1940, **5**, 619.
[7] Fieser and Creech, *J. Amer. Chem. Soc.*, 1939, **61**, 3502.
[8] Barnett and Matthews, *Chem. News*, 1925, **130**, 339.
[9] Fieser and Hershberg, . *Amer. Chem. Soc.*, 1938, **60**, 1893.

evaporated, and the residue recrystallised once from acetic acid before being chromatographed on alumina in hexane solution. After recrystallisation from hexane and finally from acetic acid, the 3-fluoropyrene was obtained as colourless needles, m. p. 137° (Found: C, 87·5; H, 4·3. Calc. for $C_{16}H_9F$: C, 87·3; H, 4·1%). The *trinitrobenzene complex*, recrystallised from hexane, had m. p. 206° (Found: C, 61·5; H, 2·8; N, 9·9. $C_{16}H_9F,C_6H_3O_6N_3$ requires C, 61·1; H, 2·6; N, 9·7%). A picrate, m. p. 186—187°, was formed in alcohol, but was unstable.

(ii) A boiling solution of 2-aminochrysene (20 g.) in acetone (500 c.c.) was poured into 1·5% hydrochloric acid (2 l.) with vigorous mechanical striring. The resulting finely divided hydrochloride was then diazotised and converted into the fluoroborate as described above. The resulting diazonium fluoroborate (28 g.) was finely crushed and decomposed in a 500 c.c. flask by direct heating until decomposition started. When the vigorous reaction had abated the temperature was kept at 195° for 1 min. The residue was extracted with benzene, the benzene evaporated, and the product chromatographed on alumina in carbon tetrachloride. The resulting 2-*fluorochrysene* (17 g.) had m. p. 192—195°, and after repeated recrystallisation from benzene and from carbon tetrachloride was obtained as colourless prisms, m. p. 197—198° (Found: C, 87·9; H, 4·5; F, 7·9. $C_{18}H_{11}F$ requires C, 87·8; H, 4·5; F, 7·7%).

(iii) 4′-Amino-1 : 2-benzanthracene (4·4 g.) was dissolved in acetone, and 30% hydrochloric acid (5 c.c.) added. The fine yellow precipitate was suspended in water (50 c.c.) and 30% hydrochloric acid (5 c.c.), and diazotised and converted into the fluoroborate as described above. The dry diazonium fluoroborate was suspended in xylene (75 c.c.) which was then boiled for 5 min. The product was chromatographed on alumina in carbon tetrachloride (yield 0·75 g.) and further purified by recrystallisation from ethanol and hexane. 4′-*Fluoro*-1 : 2-*benzanthracene* formed colourless plates, m. p. 170—170·5° (Found: C, 88·3; H, 4·5. $C_{18}H_{11}F$ requires C, 87·8; H, 4·5%).

Direct Substitution of Pyrene.—Only unchanged pyrene was isolated following the attempted fluorination of pyrene with *p*-tolyliodofluoride according to Garvey, Halley, and Allen.[2] The following experiment is typical of several under somewhat different conditions.

A suspension of *p*-iodosotoluene (15 g.) in water (100 c.c.) and hydrofluoric acid (20 c.c.; 46%) was added to a solution of pyrene (10 g.) in chloroform (150 c.c.) at 50° in a Pyrex flask. The flask was then shaken until all the solid had dissolved, an additional 5 c.c. of hydrofluoric acid being added if necessary. After being kept in the dark at room temperature with occasional shaking for 72 hr., the mixture was steam-distilled. The resulting solid was dried and purified by chromatography on alumina in carbon tetrachloride. Evaporation of the eluate gave a yellow solid (5 g.) which was extracted with boiling ethanol. The insoluble fraction was recrystallised from benzene, to give light yellow 3 : 3′-dipyrenyl (?), m. p. 325—326° after softening at 317° (vac.) (Found: C, 95·0; H, 4·8. Calc. for $C_{32}H_{22}$: C, 95·5; H, 4·5%). Vollmann *et al.*[5] give m. p. 319—320°.

The alcohol-soluble fraction was recrystallised successively from acetone, ethanol, and hexane. 3-Chloropyrene (0·5 g.) was obtained as colourless blades, m. p. 119·5—120·5°, not depressed by admixture with a specimen prepared from pyrene and sulphuryl chloride (Vollmann *et al.*[5]). The ultraviolet absorption spectrum in ethanol was identical with that given by Friedel and Orchin.[11]

In a further experiment, a mixture of *p*-iodosotoluene (12·5 g.) in acetic acid (50 c.c.) and 40% hydrofluoric acid (10 c.c.) was added with stirring to pyrene (5 g.) in acetic acid (150 c.c.) at 55°. After 72 hr. the mixture was poured into boiling water, and the product collected. 3 : 3′-Dipyrenyl, m. p. 320—324°, was again isolated, and fractional recrystallisation of the complex with picric acid gave pyrene picrate, m. p. and mixed m. p. 217—219°, and 3-fluoropyrene picrate (30 mg.), m. p. 186—187°, also undepressed by admixture with a specimen prepared as described above.

Direct Substitution of Chrysene.—The following was typical of a number of experiments in which modified conditions were used. A suspension of *p*-iodosotoluene (40 g.) in water (50 c.c.) and 40% hydrofluoric acid (40 c.c.) was added to chrysene (10 g.) in *s*-tetrachloroethane (300 c.c.) at 55°. The reaction was then allowed to proceed at room temperature, in the dark, for 72 hr., after which the mixture was steam-distilled. Purification of the solid by chromatography on alumina, in carbon tetrachloride (yield 7 g.; m. p. 145—153°), followed by recrystallisation from benzene, gave 2-chlorochrysene, m. p. 155—156°, unchanged by further recrystallisation, vacuum-sublimation, or purification through the trinitrobenzene complex, m. p. 164·5—165·5°. It was identified by a direct comparison with a specimen prepared from chrysene and sulphuryl

[10] Stanley, McMahon, and Adams, *J. Amer. Chem. Soc.*, 1933, **55**, 706.
[11] Friedel and Orchin, "Ultraviolet Spectra of Aromatic Compounds," Wiley, New York, 1951.

chloride.[12] The trinitrobenzene complex prepared from authentic 2-chlorochrysene had m. p. 167—168°, but it dissociated too readily to be analysed. Similarly the picrate had m. p. 142—143°, and was also unstable.

Direct Substitution of 1 : 2-*Benzanthracene*.—No success was obtained by the general method of Garvey, Halley, and Allen.[1]

A solution of *p*-iodosotoluene (12·5 g.) in acetic acid (50 c.c.) and 40% hydrofluoric acid (10 c.c.) was added with stirring to 1 : 2-benzanthracene (5 g.) in glacial acetic acid (200 c.c.). After 72 hr. the mixture was poured into water, and the solid collected, steam-distilled to remove *p*-iodotoluene, and extracted with carbon tetrachloride. Evaporation of the solvent, followed by recrystallisation from acetic acid and sublimation at 100°/0·03 mm., gave a *difluoro*-1 : 2-*benzanthracene* (25 mg.), m. p. 144—144·5° (Found: C, 81·8; H, 3·9. $C_{18}H_{10}F_2$ requires C, 81·8; H, 3·8%).

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[12] Vollmann and Becker, Fr. Pat. 793,893; *Chem. Abs.*, 1936, **30**, 4516.