from the residual tar. The residue was heated under reflux overnight with an additional 25 ml. of concd. hydrochloric acid. The combined acid solutions were made basic and extracted with ether. The ether extracts were washed, dried, and the ether was evaporated. The residue was crystallized from benzene–petroleum ether (b.p. 60–90°) and gave 2.85 g. (60%) of amine, m.p. 126–128°. The analytical sample had m.p. 129–129.5°.

*Anal.* Calcd. for $C_{12}H_{15}NO$: C, 76.14; H, 8.00; N, 7.40. Found: C, 76.00; H, 8.16; N, 7.46.

*8-Hydroxy-1-benzocyclooctanone* (VIId). A solution of 0.5 g. of sodium nitrite in 3 ml. of water was added dropwise to a solution of 0.95 g. of amine (VId) in 5 ml. of water and 2 ml. of concd. hydrochloric acid at 0°. The resulting diazonium salt solution was then added to a stirred solution of 8 ml. of sulfuric acid and 12 ml. of water at 90–100°. The solution was stirred for 2 min., cooled, and extracted with ether. The ether solution was washed with water, dried over magnesium sulfate, and the ether was evaporated. The product was recrystallized from ether-pentane to yield 0.2 g. (21%), m.p. 136.5–138.5°. Further recrystallization gave a sample with m.p. 138.5–139.5°.

*Anal.* Calcd. for $C_{12}H_{14}O_2$: C, 75.76; H, 7.42. Found: C, 75.30; H, 7.41.

*8-Fluoro-1-benzocyclooctanone* (Xd). To a solution of 2.37 g. of amine (VId) in 4 ml. of hydrochloric acid and 6 g. of ice was added a solution of 1.05 g. of sodium nitrite in 4 ml. of water, keeping the temperature below 5°. With continued cooling and stirring 3.0 ml. of 48% fluoroboric acid was then added. The mixture was stirred at 0° for 0.5 hr., cooled to −10°, and filtered. The fluoroborate salt was washed with 5 ml. of cold methanol and with cold ether, then was dried. There was obtained 3.04 g. of salt, m.p. 82–85° dec. The dry salt was decomposed by refluxing in 50 ml. of toluene for 1 hr. The toluene solution was washed with dilute sodium hydroxide and water, and then dried. The solvent was removed and the residue was distilled to yield 1.4 g. (59%) of product, b.p. 93–94° (0.4 mm.), $n_D^{22}$ 1.5424.

*Anal.* Calcd. for $C_{12}H_{13}FO$: C, 74.98; H, 6.82; F, 9.89. Found: C, 74.68; H, 6.99; F, 9.74.

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[CONTRIBUTION FROM THE EVANS CHEMISTRY LABORATORY OF THE OHIO STATE UNIVERSITY]

# The Syntheses of 1′-Fluoro- and 1′-Fluoro-10-methyl-1,2-benzanthracene[1]

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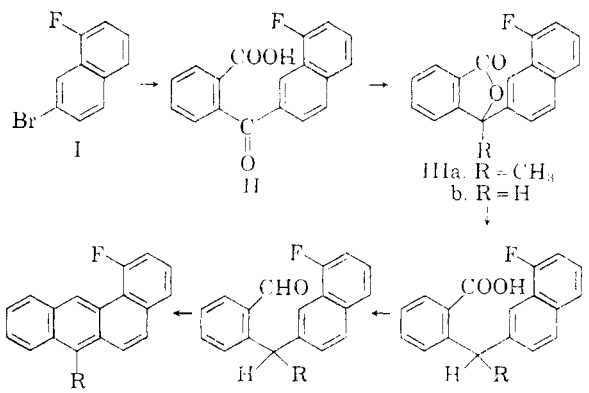
The syntheses of 1′-fluoro-1,2-benzanthracene, VIb, and 1′-fluoro-10-methyl-1,2-benzanthracene, VIa, were accomplished in good yield by a new method involving cyclization of *o*-(8-fluoro-2-naphthylmethyl)benzaldehyde, Vb, and of *o*-[1-(8-fluoro-2-naphthyl)ethyl]benzaldehyde, Va, respectively, by heating with polyphosphoric acid. An attempt to synthesize 1′-fluoro-9,10-dimethyl-1,2-benzanthracene by a similar cyclization of *o*-[1-(8-fluoro-2-naphthyl)ethyl]acetophenone failed, undoubtedly because of steric factors.

The reasons for the synthesis of monofluoro methyl-1,2-benzanthracenes have been stated.[2] In this paper the synthesis of 1′-fluoro-1,2-benzanthracene, VIb, and of 1′-fluoro-10-methyl-1,2-benzanthracene, VIa, as outlined in the chart below are described.




VIa. (R = $CH_3$). Va. (R = $CH_3$). IVa. (R = $CH_3$).
b. (R = H). b. (R = H). b. (R = H).

(1) This work was supported by a grant from the National Institutes of Health.

(2) M. S. Newman, D. MacDowell, and S. Swaminathan, *J. Org. Chem.*, **24**, 509 (1959).

The required 7-bromo-1-fluoronaphthalene, I, was prepared in three steps (44% overall yield) from 7-bromo-1-methylnaphthalene[3] by (1) oxidation to 7-bromo-1-naphthoic acid[4] using aqueous potassium dichromate[5] at 235°; (2) conversion of this acid to 7-bromo-1-naphthylamine (not isolated) by the Schmidt reaction;[6] and (3) replacement of the amino group by fluorine by the Rutherford modification[7] (hexafluorophosphoric acid) of the Schiemann reaction. Some modifications and improvement in the synthesis of 7-bromo-1-methylnaphthalene[3] were effected, the main one being in the use of chloranil for the dehydrogenation of 7-bromo-1-methyl-3,4-dihydronaphthalene to 7-bromo-1-methylnaphthalene.

(3) L. F. Fieser and A. M. Seligman, *J. Am. Chem. Soc.*, 60, 170 (1938).

(4) H. Goldstein and H. A. Fischer, *Helv. Chim. Acta*, 21, 1921 (1938).

(5) M. S. Newman and H. Boden, *J. Org. Chem.*, **26**, 1759 (1961). See ref. 4 in this paper for information concerning this oxidation.

(6) H. Wolff in Organic Reactions, John Wiley and Sons, Inc., New York, N. Y., 1946, Vol. III, p. 307.

(7) We are greatly indebted to Dr. K. Rutherford, Essex College, Windsor, Canada, for information about this method soon to be published.

The Grignard reagent of 7-bromo-1-fluoronaphthalene, I, was formed satisfactorily only when one equivalent of ethylene dibromide was used.[8] Reaction of this reagent with phthalic anhydride led to the ketoacid II in 69% yield which is high for this type of reaction (*e.g.*, ref. 3). We have insufficient experience with Grignard reagents prepared using an equivalent of ethylene dibromide to tell if this factor accounts for the high yield or whether the particular halide used is responsible. This point is worthy of further study.

Both the lactone, IIIa, and the ketoacid, II were reduced to IVa and IVb, respectively, by the zinc and formic acid method.[9] As attempts to prepare VIa and b from IVa and b by conventional methods involving the corresponding anthrones[3,10] either failed or gave very poor yields, an alternate route was sought. Reduction of the acids IVa and b to the corresponding primary alcohols (not isolated pure) followed by oxidation with chromic oxide–pyridine reagent[11] afforded the aldehydes, Va and b, (not isolated pure) which were readily cyclized by polyphosphoric acid to the desired fluoro-1,2-benzanthracenes, VIa and b, in overall yields of 50–55% from the acids IVa and b.

Acid IVa on treatment with methyllithium was converted into *o*-[1-(8-fluoro-2-naphthyl)-ethyl]acetophenone in the hope that this could be cyclized to 1′-fluoro-9,10-dimethyl-1,2-benzanthracene. However, all attempts at cyclization failed to yield products having the 1,2-benzanthracene ring system as judged by ultraviolet spectral analysis. Evidently, the hindrance of the 1′-fluoro and 9-methyl substitutents proved too great to allow ring closure to an analog of 1′,9-dimethyl-1,2-benzanthracene[12] to occur.

The first projected synthesis of VIa involved condensation of phthalic anhydride with 8-fluoro-1-naphthylmagnesium bromide. However, as poor yields (20–25%) of impure 1-bromo-8-fluoronaphthalene were obtained in attempts to replace the amino group of 1-bromo-8-naphthylamine by fluorine, this approach was abandoned.

## EXPERIMENTAL[13]

*β-(p-Bromobenzoyl)propionic acid.* To a stirred mixture of 800 ml. of bromobenzene and 500 g. of succinic anhydride in 1.5 l. of *o*-dichlorobenzene was added 1.43 kg. of anhydrous aluminum chloride during 30 min. The stirred reaction mixture was held at 80–90° for 6 hr. and then poured on ice and hydrochloric acid. There was obtained 1040 g. (80%) of acid as a colorless solid, m.p. 142–144°, suitable for the next step (compare ref. 3).

*γ-(4-Bromophenyl)butyric acid.* By a modified Wolf-Kishner reduction[14] (45 min. heating at 180–190°), the reduced acid,[3] m.p. 68–70°, was obtained in 85% yield without the formation of any debrominated reduced acid as described.[3]

*7-Bromo-1-tetralone.* In a typical run a solution of 200 g. of γ-(4-bromophenyl)butyric acid in 2 kg. of polyphosphoric acid[15] was held at 70° for 1 hr. and then poured on ice. After an alkaline extraction of the products showed that no unchanged acid was present, the solvent was removed from the neutral fraction and the residue crystallized from ether-Skellysolve F (petroleum ether b.p. 40–50°) to yield 150 g. (80%) of 7-bromo-1-tetralone, m.p. 71–73°, suitable for use in the next step.

*7-Bromo-1-methyl-3,4-dihydronaphthalene.* This compound, b.p. 120–125° at 5 mm. was prepared in 89% yield using the above ketone and methylmagnesium bromide (Arapahoe Chemicals, Inc., Boulder, Colo.) as described.[3]

*7-Bromo-1-methylnaphthalene.* A solution of 350 g. of 7-bromo-1-methyl-3,4-dihydronaphthalene and 800 g. of chloranil in 2.5 l. of toluene was refluxed for 18 hr. On cooling, the chloranil which separated was filtered. The filtrate was concentrated to about 500 ml. under reduced pressure and the chloranil again filtered. The filtrate was washed with dilute alkali containing sodium hydrosulfite. After removal of solvent, vacuum distillation afforded 300 g. (85%) of 7-bromo-1-methylnaphthalene, b.p. 105–110° at 0.5 mm., suitable for the next step.

*7-Bromo-1-naphthoic acid.* In a typical run a mixture of 25 g. of 7-bromo-1-methylnaphthalene and a solution of 60 g. of potassium dichromate in 400 ml. of water was shaken in a bomb at 235 ±5° for 18 hr. About 2–3 g. of 7-bromo-1-methylnaphthalene was recovered from the neutral fraction and 18 g. (70%) of 7-bromo-1-naphthoic acid,[4] m.p. 231–233°, was obtained from the acid fraction,[16] after recrystallization from acetic acid.

*7-Bromo-1-fluoronaphthalene* (I). In a typical experiment 35 g. of sodium azide was added to a stirred suspension of 125 g. of 7-bromo-1-naphthoic acid in 1 l. of concentrated sulfuric acid at 5–10°. Considerable frothing occurred. After the evolution of gas moderated, the mixture was allowed to cool to room temperature and was then warmed to 40° for 10 min. On adding to ice a colorless precipitate of 7-bromo-1-naphthylammonium sulfate separated. This was collected by filtration and suspended in 1 l. of water containing 100 ml. of concentrated sulfuric acid. After adding a solution of 35 g. of sodium nitrite in 100 ml. of water while maintaining the temperature at 0–5°, 150 ml. of 65% hexafluorophosphoric acid[17] was added. The precipitate which formed was collected, washed with water, methanol, and ether and dried over phosphorus pentoxide to yield 150 g. of diazonium fluorophosphate,[7] m.p. 130–132° w. decomp. This solid was added in portions to boiling xylene[18] for smooth decomposition. The crude vacuum distilled product was washed with concentrated sulfuric acid and distilled to yield 50 g. of 7-bromo-1-fluoronaphthalene, b.p. 95–100° at 0.5 mm., as a colorless oil. The overall yield from 7-bromo-1-naphthoic acid was 44%.

*Anal.* Calcd. for $C_{10}H_6BrF$: C, 53.2; H, 2.7; Br, 35.4; F, 8.1. Found: C, 53.3; H, 2.7; Br, 35.6; F, 8.4.

(8) D. E. Pearson, D. Cowan, and J. D. Beckler, *J. Org. Chem.*, **26**, 97 (1961).

(9) R. L. Letsinger, J. D. Jamison, and A. S. Hussey, *J. Org. Chem.*, **26**, 97 (1961).

(10) L. F. Fieser and M. S. Newman, *J. Am. Chem. Soc.*, **58**, 2376 (1936).

(11) G. I. Poos, *et al.*, *J. Am. Chem. Soc.*, **75**, 422 (1953).

(12) M. S. Newman, W. C. Sagar, and M. V. George, *J. Am. Chem. Soc.*, **82**, 2376 (1960).

(13) All melting points are uncorrected. Analyses by Schwarzkopf Microanalytical Laboratory, Woodside 77, N. Y.

(14) Huang-Minlon, *J. Am. Chem. Soc.*, **68**, 2487 (1946).

(15) We express our appreciation to the Victor Chemical Co., Chicago, Ill., for a generous gift of polyphosphoric acid.

(16) In this instance the control of temperature in the oxidation appears to be critical, whereas in other cases (see ref. 5) the yields are not so sensitive to the temperature of oxidation.

(17) Ozark Mahoning Co., Tulsa, Okla.

(18) For use of xylene in Schiemann reaction see T. L. Fletcher and M. J. Namking, *Chem. & Ind.*, 179 (1961).

*o-(8-Fluoro-2-naphthoyl) benzoic acid* (II). In a typical reaction a solution of 20.0 g. of I and 17 g. of ethylene dibromide[8] in 100 ml. of ether was added to 5.5 g. of magnesium[19] in 30 ml. of ether during 1 hr. This solution was added rapidly to a solution of 15 g. of phthalic anhydride in 200 ml. of warm benzene with vigorous stirring and the mixture refluxed 2 hr. A conventional workup yielded 18 g. (69%) of II as a pale yellow solid, m.p. 173–175°.

*Anal.* Calcd. for $C_{18}H_{11}FO_3$: C, 73.5; H, 3.8; F, 6.5. Found: C, 73.7; H, 3.9; F, 6.3.

*3-Methyl-3-(8-fluoro-2-naphthyl)phthalide* (III). To a solution of 11 g. of II in 500 ml. of ether was added slowly with vigorous stirring 40 ml. of 3*M* methylmagnesium bromide (Arapahoe). After refluxing for 1 hr., the mixture was decomposed with dilute acid to yield 8.8 g. (80%) of IIIa suitable for further treatment. A pure sample of IIIa, m.p. 144–145°, was obtained by recrystallization from benzene-Skellysolve F, with little loss.

*Anal.* Calcd. for $C_{19}H_{13}FO_2$: C, 78.1; H, 4.5; F, 6.5. Found: C, 78.3; H, 4.6; F, 6.5.

*o-[1-Fluoro-2-naphthyl)ethyl]benzoic acid* (IVa). A mixture of 35 g. of zinc dust, 17 g. of IIIa, 350 ml. of 85% formic acid,[9] and 70 ml. of water was refluxed for 18 hr. Crystallization of the acid fraction of the products yielded 14 g. (82%) of colorless IVa, m.p. 160–161°.

*Anal.* Calcd. for $C_{19}H_{15}FO_2$: C, 77.6; H, 5.1; F, 6.5. Found: C, 77.5; H, 5.1; F, 6.3.

*1'-Fluoro-10-methyl-1,2-benzanthracene* (VIa). A solution of 10 g. of IVa in ether was added to an etheral solution of 1.5 g. of lithium aluminum hydride and the mixture refluxed for 2 hr. A solution of the crude primary alcohol thus produced in 100 ml. of pyridine was added to a solution of 10 g. of chromic oxide in 100 ml. of pyridine and the solution left for 2 hr. at 20°. The crude aldehyde obtained after removal of the pyridine with acid and any IVa with alkali was used without further purification by dissolving in 100 g. of polyphosphoric acid. After heating on the steam bath for 15 min., the addition of ice caused a yellow solid to separate. A benzene solution of this solid was chromatographed on alumina to yield 5 g. (overall yield from IVa, 56%) of colorless VIa, m.p. 125–126°.

*Anal.* Calcd. for $C_{19}H_{13}F$: C, 87.7; H, 5.0; F, 7.3. Found: C, 88.0; H, 5.1; F, 7.0.

The 2,4,7-trinitrofluorenone complex[20] crystallized from benzene-acetic acid as brown needles, m.p. 233–234°.

*Anal.* Calcd. for $C_{32}H_{18}FN_3O_7$: C, 66.8; H, 3.1; N, 7.3. Found: C, 66.8; H, 3.2; N, 7.2.

*o-(8-Fluoro-2-naphthylmethyl)benzoic acid* (IVb). By a zinc and formic acid reduction[9] similar to that of IIIa, 5.0 g. of II was converted into 3.0 g. (63%) of IVb, m.p. 145–147° and 0.8 g. (17%) of 2-(8-fluoro-2-naphthyl) phthalide, IIIb, m.p. 154–156°. The analytical sample, m.p. 146–148°, of IVb was obtained by recrystallization from aqueous alcohol with little loss.

*Anal.* Calcd. for $C_{18}H_{13}FO_2$: C, 77.1; H, 4.7; F, 6.8. Found: C, 77.2; H, 4.7; F, 6.8.

The analytical sample, m.p. 157–158°, of IIIb was obtained by crystallization from benzene-Skellysolve F.

*Anal.* Calcd. for $C_{18}H_{11}FO_2$: C, 77.7; H, 4.0. Found: C, 77.8; H, 4.1.

*1'-Fluoro-1,2-benzanthracene* (VIb). By a procedure similar to that used for conversion of IVa to VIa, 5.0 g. of IVb was converted into VIb, colorless elongated prisms, m.p. 113–114°, from benzene-methanol, in 50% overall yield.

*Anal.* Calcd. for $C_{18}H_{11}F$: C, 87.8; H, 4.5; F, 7.7. Found: C, 87.8; H, 4.6; F, 7.5.

The 2,4,7-trinitrofluorenone complex crystallized from benzene–acetic acid as scarlet needles, m.p. 234–235°.

*Anal.* Calcd. for $C_{31}H_{16}FN_3O_7$: C, 66.3; H, 2.9; N, 7.5. Found: C, 66.8; H, 3.2; N, 7.4.

*o-[1-(8-Fluoro-2-naphthyl)ethyl]acetophenone.* Treatment of 3.0 g. of IVa in ether with excess methyllithium at room temperature for 1 hr. followed by a conventional workup yielded 1.0 g. (34%) of the corresponding methyl ketone, m.p. 93–95°.

*Anal.* Calcd. for $C_{20}H_{17}FO$: C, 82.2; H, 5.8; F, 6.5. Found: C, 82.1; H, 6.0; F, 6.5.

The 2,4-dinitrophenylhydrazone[21] crystallized from benzene-methanol as orange needles, m.p. 180° after softening at 165°.

*Anal.* Calcd. for $C_{26}H_{21}FN_4O_4$: C, 66.1; H, 4.4; N, 11.9. Found: C, 66.3; H, 4.6; N, 11.8.

Treatment of the above ketone with polyphosphoric acid on the steam bath for 15 min. (compare the the cyclization of Va) yielded a dark oil which could not be crystallized and whose ultraviolet absorption spectrum gave no indication of the 1,2-benzanthracene structure.

*1-Bromo-8-aminonaphthalene.* This amine was prepared by the deamination of 1-bromo-5-amino-8-nitronaphthalene[22] to 1-bromo-8-nitronaphthalene[23] (in 70–75% yield) as described for a similar case,[24] followed by reduction of the latter by an improved procedure.

To a mixture of 50 g. of 1-bromo-8-nitronaphthalene in 400 ml. of ethanol was added 25 g. of iron powder and 3 ml. of concentrated hydrochloric acid. The mixture was refluxed and after 1 and 2 hr., 25 g. portions of iron powder and 3 ml. portions of acid were added. The reaction mixture was made slightly alkaline 1 hr. after the last addition of reagents and filtered hot. The alcohol was removed from the filtrate by distillation and the amine was taken into dilute hydrochloric acid. On making the filtered acid extract basic a buff colored precipitate was obtained which on crystallization from aqueous alcohol yielded 30 g. (68%) of 1-bromo-8-naphthylamine,[25] m.p. 86–88°.

This amine was converted into the diazonium hexafluorophosphate, as described for a similar case.[26] However, on heating above its decomposition point (about 125°), a low yield of impure product (which had only about 50% of the expected fluorine content) was obtained. Hence, further work on a synthetic route employing 1-bromo-8-fluoronaphthalene as starting material was abandoned.

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(19) We are greatly indebted to the Dow Co., Midland, Mich., for a generous supply of sublimed magnesium. In our experience, Grignard reagents made with sublimed magnesium are much lighter in color than those prepared from ordinary magnesium.

(20) M. Orchin and E. O. Woolfolk, *J. Am. Chem. Soc.*, **68**, 1727 (1946).

(21) Prepared by the method of G. D. Johnson, *J. Am. Chem. Soc.*, **73**, 5888 (1951).

(22) K. Fries and E. Kohler, *Ber.*, **57**, 496 (1924).

(23) R. Meldola and F. W. Streatfeild, *J. Chem. Soc.*, **63**, 1054 (1893).

(24) M. P. Cava and J. F. Stucker, *J. Am. Chem. Soc.*, **79**, 1706 (1957).

(25) L. F. Fieser and A. M. Seligman, *J. Am. Chem. Soc.*, **61**, 136 (1939).

(26) M. S. Newman and R. H. B. Galt, *J. Org. Chem.*, **25**, 214 (1960).