addition of further isopropenyl acetate. The mixture was cooled to 10°, diluted with 600 ml. of ethyl ether, the organic solution was washed with 250 ml. of a cold 3% sodium bicarbonate solution, and with water to neutrality. The solution was dried over sodium sulfate, concentrated to dryness, and the residue was taken up with 800 ml. of hexane. The solution was passed through a column containing 80 g. of Florisil (the column had been washed with fresh hexane). The eluate was concentrated to a volume of 150 ml., then 15 ml. of methanol was added, the resulting white crystalline product was filtered, dried (19 g., m.p. 103–113°), and recrystallized from methanol giving 14.5 g. of VIII, m.p. 111–116°, which was used for the next step. The product, further recrystallized from CH_3OH, melted at 115–119°; $[\alpha]^{22}D$ −99.8° (*c* 0.5, $CHCl_3$); λ_{max} 239 (CH_3OH); $E_{1\,cm.}^{1\%}$ 182.2 (CH_3OH). Infrared (Nujol mull) 1762 (C=O acetate), 1720 (C=O formate), 1645 (C_{20}=C_{21}), 1597 (C_{16}=C_{17}) cm.$^{-1}$.

Anal. Calcd. for $C_{25}H_{34}O_4$ (m.w. 398.54): C, 75.35; H, 8.60. Found: C, 74.99; H, 8.67.

16-Methyl-21-iodo-pregna-5,16-diene-3β-ol-20-one 3-Formate (IX).—To a suspension of 24 g. of VIII (m.p. 111–116°) in 85 ml. of dioxane 15.6 g. of N-iodosuccinimide was added under stirring. The mixture was heated for 45 min. at 80 ± 5° under a nitrogen stream, then poured into 200 ml. or a cold aqueous solution of 10% sodium metabisulfite. A solid product separated and after a short stirring was collected; 28.5 g. of crude 21-iodo derivative melting at 112–120° was obtained and used for the next step.

The product repeatedly crystallized from chloroform–methanol melted at 142–144°. $[\alpha]D$ −106 ± 2° (*c* 0.5, $CHCl_3$); λ_{max} 265 (CH_3OH); $E_{max}^{1\%}$ 124.2 (CH_3OH). Infrared (Nujol mull): 1700 (C=O formate), 1637 (C_{20}=O), 1595 (C_{16}=C_{17}).

Anal. Calcd. for $C_{23}H_{31}O_3J$: J, 26.31. Found: J, 26.18.

16-Methylpregna-5,16-diene-3β,21-diol-20-one 3-Formate 21-Acetate (X).—To a solution of 19 g. of IX in 240 ml. of acetone 88 ml. of glacial acetic acid was added, followed, after cooling to 10–15°, by 140 ml. of triethylamine.[17] The mixture was refluxed for 45 min., diluted with 2300 ml. of water, and allowed to stand for 1 hr. Then 20 g. of Celite was added and the solid was collected. The cake was carefully washed with water, dried, and extracted many times with a total volume of 500 ml. of warm acetone. The extracts were concentrated to a small volume giving a crystalline compound; 12 g.; m.p. 155–160°. From the mother liquors, by concentration and addition of ether, a further crop of 2.3 g. of product melting at 155–160° was obtained. The combined crops were recrystallized from 95% ethanol giving 11.4 g. of X; m.p. 150–162°. This product was used as such for the following step. A sample, after many crystallisations from ethanol, melted at 161–162°. $[\alpha]D$ −88° (*c* 1, $CHCl_3$); λ_{max} 252 (95% EtOH); $E_{1\,cm.}^{1\%}$ 212 (95% EtOH). Infrared (Nujol mull), 1742 (C=O acetate), 1708 (C=O formate), 1658 (C_{20}=O), 1600 (C_{16}=C_{17}) cm.$^{-1}$.

Anal. Calcd. for $C_{25}H_{34}O_5$: C, 72.44; H, 8.26. Found: C, 72.26; H, 7.99.

16β-Methylpregna-5-ene-3β,21-diol-20-one 3-Formate 21-Acetate (XI).—A solution obtained by dissolving 8.5 g. of X in 4000 ml.[18] of hot ethanol was rapidly cooled to 30°. Then 25 g. of Raney nickel was added and the mixture was hydrogenated under atmospheric pressure at room temperature until a sample, filtered and diluted with methanol, showed no more absorbance at 252 mμ (disappearance of =C=O conjugated with a double bond). This required 3–4 hr. The catalyst was removed by filtration and the resulting solution was concentrated under reduced pressure. The dry white solid residue (9 g.; m.p. 131–135°) was recrystallized from isopropyl ether giving 6 g. of a product melting at 139–142°. During the hydrogenation a partial hydrolysis of the formyl ester at position 3 occurred. The resulting product was used as such for the next step.

16β-Methylpregna-4-ene-21-ol-3,20-dione 21-Acetate (16β-Methyl DOCA) (V).—A solution of 6 g. of crude XI in 240 ml. of anhydrous toluene and 96 ml. of cyclohexanone was distilled until 40 ml. of toluene was removed. To the resulting completely anhydrous solution 6 g. of aluminum isopropoxide dissolved in 48 ml. of anhydrous toluene was added in 5 min. The reaction mixture was heated at reflux under stirring for 2 hr. The working up of the product was carried out as described above for V and gave 1.9 g. of 16β-methyl DOCA, which was found identical with the product previously obtained.

16β-Methyl-17α-pregna-4-ene-21-ol-3,20-dione 21-Acetate (XII).—To a solution of 300 mg. of V in 30 ml. of methanol 0.3 g. of potassium hydroxide dissolved in 1 ml. of water was added with stirring under a nitrogen atmosphere and the mixture was refluxed for 1 hr. After dilution with 40 ml. of water, the methanol was removed *in vacuo*. The resulting crystalline product which was collected, washed with water, and dried (220 mg.) was dissolved in 2 ml. of pyridine and mixed with 2 ml. of acetic anhydride.[1] After standing overnight the solution was poured into 25 ml. of water previously acidified with hydrochloric acid. After 30 min. stirring the mixture was extracted three times with a total of 60 ml. of methylene chloride. The organic extract was washed with 0.1 *N* hydrochloric acid, 2% sodium bicarbonate solution, and water; then it was dried over sodium sulfate and evaporated to dryness. The residue was taken up with benzene and filtered through 4 g. of neutral aluminum oxide. The filtered benzene (about 200 ml.) was evaporated to dryness and the residue (150 mg.) recrystallized from methanol. Eighty milligrams of XII melting at 161–162° was recovered. $[\alpha]D$ +20 (*c* 0.802, $CHCl_3$); $[\alpha]D$ +2.3 (*c* 0.789, dioxane). Infrared (chloroform solution *c* 2.5) 1743 (C=O acetate), 1718 (C_{20}=O), 1660 (C_3=O), 1613 (C_4=C_5) cm.$^{-1}$.

Anal. Calcd. for $C_{24}H_{34}O_4$ (386.5): C, 74.58; H, 8.81; Found: C, 74.37; H, 8.96.

A sample of 16α-methyl DOCA, when subjected to a similar treatment, did not give raise to isomerization in detectable extent. Most of the starting material was therefore recovered unchanged.

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(17) W. T. Moreland, Jr., *J. Org. Chem.*, **21**, 820 (1956); see also E. S. Rothman, T. Perlstein, and M. E. Wall, *ibid.*, **25**, 1966 (1960).

(18) Since the product has a low solubility, it was advisable to hydrogenate rapidly to avoid the separation of crystals.

The Preparation of Fluorinated Anthraquinones and Fluorinated Substituted Anthraquinones[1]

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The first fluorinated anthraquinones to be made were those by Hahn and Reid,[2] who have re-

ported the preparation of 1- and 2-fluoroanthraquinones by condensing phthalic anhydride with fluorobenzene and *p*-fluorotoluene. Although the 2-fluoroanthraquinone prepared in this manner was positively identified, there is less certainty about the preparation of 1-fluoroanthraquinone. Further, 2-fluoroanthraquinone can be prepared by a Diels–Alder synthesis from fluoroprene and maleic anhydride.[3] The 1- and 2-diazonium fluoroborates are also known,[4a] but the suggested decomposition in acetone in the presence of copper powder or cuprous chloride was criticized,[4b] and the reported 1-fluoroanthraquinone of m.p. 125–127° seems to be mixed to a large extent with impurities. Consequently, only the 2-fluoroanthraquinone is available, from which some new dyes, characterized by marked light fastness, have been prepared.[5]

Aminoanthraquinones were diazotized in concentrated sulfuric acid solution using nitrosylsulfuric acid as the diazotizing agent[6]; phosphorous acid[7] was not found to be essential, and a 10% excess of diazotizing agent led to complete diazotization in all cases studied. All aminoanthraquinones reported in Table I gave diazonium sulfates that could be precipitated when the reaction mixture was poured into the necessary quantity of ice. This insolubility, however, holds only for the resulting concentrated sulfuric acid solution; it was found that, contrary to reports in the literature regarding the insolubility in water of anthraquinone diazonium sulfates[8] these salts could be dissolved in water to stable solutions. When fluoroboric acid is added to such a solution, a rapid precipitation of the diazonium fluoroborates occurs. Heating of the solution[9] should be avoided since around 60° a slow nitrogen and boron trifluoride discharge was observed. Where, because of poor solubility, large volumes of water are needed the precipitation of the diazonium fluoroborates is carried out in a water suspension. The sulfuric acid for the diazotization should be at least 70% in which case the fluoroboric acid in 40% solution could be added, with cooling and stirring, to the solution resulting from the diazotization, without being further diluted with water.

Mono-, di-, and trisubstituted aminoanthraquinones were similarly treated to yield stable diazonium fluoroborates. It was found that such substituents as —Cl, —OCH_3 in H position *para* to the diazonium group resulted in more water-soluble products. This effect is pronounced in the 4-methoxyanthraquinone 1-diazonium fluoroborate. In the case of the carboxyl group present, the diazonium fluoroborates which are slightly soluble in water are very soluble in alcohol or acetone.

A thermal decomposition[10] of the dried salt by heating in a suitable apparatus, similar to that used in the ordinary Schiemann reaction,[11] is not advisable in the present case; the decomposition is followed by sublimation of the products, which causes difficulties. Because of some moisture kept by the salt, hydroxyanthraquinones are formed as impurities which are very difficult to remove. This problem was successfully overcome by decomposition being performed in an inert organic solvent.[12] As solvents, stable nonhydroxylic compounds of boiling point a little higher than the decomposition temperature can be used. The powdered anthraquinone fluoroborates are suspended in such a solvent and the solution is slowly, under stirring, brought to boil. The slow, well controlled decomposition is followed by the evolution of the white vapor of boron trifluoride. The chlorobenzenes were found most suitable and, accordingly, were used. Nitrobenzene was also used in one case, but less satisfactorily. With the pyrolysis in inert organic solvents, the moisture present in the salt does not interfere, and the fluoroanthraquinones are obtained free of hydroxyanthraquinones.

All the fluoroanthraquinones prepared are yellow compounds, brighter than the anthraquinone, with slight differences in color. The compounds fluorinated in 1-positions are pale yellow compared to the bright yellow 2-fluorinated anthraquinones. They possess sharp melting points, followed by sublimation. The 1-fluorinated compounds, when treated with such nucleophiles as S^{--}, RO^-, OH^- exchange the fluorine for the nucleoplile; when treated with substituted amines the reaction leads to N-substituted aminoanthraquinones.[13] The 2-fluorinated compounds, on the other hand, are very stable towards such a treatment.

Experimental

1-Fluoroanthraquinone.—A 20-g. sample of 1-aminoanthraquinone was added in portions with stirring to 150 ml. of concentrated sulfuric acid. To this solution, maintained

(1) This work has been partly included in the French Patent 1,250,130, which is an extention to the German patent application, G. Valkanas, D 30,264 (March 21, 1959).

(2) F. C. Hahn and E. E. Reid, *J. Am. Chem. Soc.*, **46**, 1648 (1924).

(3) D. D. Coffman and L. F. Salisbury, U. S. Patent 2,451,612; *Chem. Abstr.*, **43**, 2218f (1949).

(4)(a) E. D. Bergmann, S. Berkovic, and R. Ikan, *J. Am. Chem. Soc.* **78**, 6037 (1956); (b) I. K. Barben and H. Suschitzsky, *Chem. Ind.* (London), 1039 (1957).

(5) (a) Swiss Patent 289,999 (July 16, 1953); *Chem. Abstr.*, **48**, 11800^e (1954) for CIBA; (b) British Patent 735,855; *Chem. Abstr.*, **50**, 5301^d (1956).

(6) M. A. Perkins, U. S. Patent 2,059,646; *Chem. Abstr.*, **31**, 551^2 (1937).

(7) G. C. Finger, F. H. Reed, and R. E. Oesterling, *J. Am. Chem. Soc.*, **73**, 152 (1951).

(8) R. Scholl, S. Hass, and H. K. Meyer, *Chem. Ber.*, **62**, 113 (1929).

(9) A. Lüthringhaus and H. Neresheimer, *Ann.*, **473**, 285 (1929).

(10) G. Balz and G. Schiemann, *Chem. Ber.*, **60**, 1188 (1927).

(11) A. Roe, for a survey of the Schiemann reaction see "Organic Reactions," Vol. V, John Wiley and Sons, Inc., New York, 1949; see also, H. A. Hodgson, St. Birtwell, and J. Walker, *J. Chem. Soc.*, 770 (1941).

(12) T. L. Fletcher, M. S. Mamkung, Hsi-Lung Pan, and W. H. Wetzel, *J. Org. Chem.*, **25**, 996 (1960).

(13) W. E. Solodar and M. S. Simon, *J. Org. Chem.*, **27**, 689 (1962).

TABLE I

Anthraquinone	Yield, %	M.p., °C.	Calcd. C	Calcd. H	Calcd. F	Calcd. Cl	Found C	Found H	Found F	Found Cl	Fluoroborates[a] Yield, %	Fluoroborates[a] Dec. temp., °C.
1-Fluoro-	57	226–227	74.4	3.1	8.42	...	74.35	3.13	8.37	...	85[b]	146–147
2-Fluoro-	68.5	203–204	74.4	3.1	8.42	...	74.45	3.07	8.31	...	95[c]	113–114
1,5-Difluoro-	53.5	230–231	68.8	2.46	15.57	...	69.1	2.47	15.24	...	95[d]	180–181
2,6-Difluoro-	65	228–229	68.8	2.46	15.57	...	69.2	2.44	15.46	...	98[c]	115–118
1-Fluoro-4-chloro-	...	164–166			7.3	13.65			7.21	13.7	82[e]	180–182
1-Fluoro-5-chloro-	42	215–216	64.5	2.3	7.3		64.3	2.3	7.17		87[f]	165–167
1-Fluoro-2-carboxylic acid-	...	219–222	66.7	2.59	7.04		66.8	2.56	6.97	...	45[e]	165–166
1-Fluoro-4-chloro-2-carboxylic acid-	...	224–225			6.23	11.65			6.1	11.8	51[e]	160–162
1-Chloro-2-fluoro-	54	183–184			7.3	13.65			7.32	13.5	77[d]	193–194
1-Fluoro-4-methoxy-	33	208–209	70.3	3.52	7.42		70.25	3.51	7.36		76[b]	188–189
1-Fluoro-2-methyl-	53	177–178	75	3.75	7.92		74.9	3.76	7.56		90[b,g]	160–161
1-Fluoro-2-methyl-4-chloro-	52	191–192	65.6	2.92	6.93	12.93	65.7	2.94	6.84	13.0	79[b]	179–180

[a] Mono- or bis- corresponding to the fluoroanthraquinones listed; precipitated from water solution of the corresponding diazonium sulfate unless indicated otherwise. Decomposition performed: [b] In *o*-dichlorobenzene. [c] In chlorobenzene. [d] In trichlorobenzene. [e] Without solvent. [f] In nitrobenzene. [g] Precipitation from water suspension.

at a temperature of 10 to 15°, a solution of 15 g. of sodium nitrite in 150 ml. of concentrated sulfuric acid was added. The gray diazonium salt solution which resulted was further stirred for 2 hr. and then poured into the necessary amount of ice. The gray precipitate formed was passed through a glass filter and when still wet dissolved in about a liter of water at 15–20°, and filtered from the impurities to yield a brownish filtrate. A 60-ml. aliquot of 40% fluoroboric acid solution was then added with stirring and yielded a heavy yellowish precipitate of **anthraquinone 1-diazonium fluoroborate**. It was filtered, washed with water to neutral, then further treated with methanol and dried *in vacuo;* yield 24.2 g. (85%). Dec. temp. 146–147°. If the diazonium sulfate removed by filtration is added to less water, a suspension is obtained. The addition of fluoroboric acid solution to such a suspension followed for 1 hr. by stirring, transforms the gray diazonium sulfate to the yellowish diazonium fluoroborate. The salt prepared in this way is produced in higher yield than in the first case (91%) but possesses a lower decomposition temperature (137–138°).

A 24.2-g. portion of the prepared salt was suspended in 150 ml. of *o*-dichlorobenzene. The suspension was slowly heated to reflux with stirring, so to avoid violent decomposition. Then after the evolution of boron trifluoride had ceased (*ca.* 1 hr.) some decolorizing carbon was added. The solution was filtered hot, and the **1-fluoroanthraquinone** crystallized from the filtrate on cooling. The crystals were filtered off and washed with methanol, until the *o*-dichlorobenzene was completely removed, and then dried. A yellow crystalline product with a m.p. of 219–221° was obtained; it was recrystallized from chlorobenzene, m.p. 234–235°, and further purified by sublimation, m.p. 234–236°.

2,6-Difluoroanthraquinone.—A 20-g. sample of 2,6-diaminoanthraquinone was added with stirring to 250 ml. of concentrated sulfuric acid. To the solution, at a temperature of 10–15° a solution of 28 g. of sodium nitrite in 250 ml. of sulfuric acid was slowly added. The gray solution resulted was further stirred for 1 hr. and then poured over ice. The precipitated bisdiazonium sulfate was filtered off and then dissolved into 2 l. of water. To the orange solution being filtered from the insolubles, 70 ml. of 40% fluoroboric acid was added. A 35-g. sample of **anthraquinone, 2,6-bisdiazonium fluoroborate** was obtained (98% yield); dec. temp. 115–116°.

The decomposition was carried out in 300 ml. of chlorobenzene. The **2,6-difluoroanthraquinone** crystallized after cooling and had a m.p. of 225–226° which after recrystallization from chlorobenzene, increased to 228–229°; yield 13 g. (65%).

Friedel-Crafts Isomerization. V.[1a] Aluminum Chloride-Catalyzed Isomerization of Terphenyls

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Examples of the migration of phenyl groups in substituted aromatics are not as numerous as for alkyl or halogen substituents.

A number of thermal rearrangements are known: the rearrangement of 1-phenyl indene to the 2-phenyl isomer,[1b] the isomerization of 1-phenyl naphthalene to 2-phenyl naphthalene,[2] and the formation of 2,3-benzfluorene from 1-*o*-anisyl naphthalene.[3] In a patent, Swisher[4] reported the isomerization of the terphenyls using varying amounts of aluminum chloride at temperatures ranging from 140 to 220° and reported the formation of 65 to 70% *m*-terphenyl. Weingarten[5] reported intra- and intermolecular halogen migration as well as intramolecular phenyl migration in the aluminum chloride–

(1a) Part IV, G. A. Olah and M. W. Meyer, *J. Org. Chem.*, **27**, 3464 (1962); (1b) I. v. Braun and G. Manz, *Ber.*, **62**, 1059 (1929).

(2) F. Mayer and R. Schiffner, *ibid.*, **67**, 67 (1934).

(3) M. Orchin and L. Reggel, *J. Am. Chem. Soc.*, **70**, 1245 (1948).

(4) R. D. Swisher, U. S. Patent 2,363, 209 (1944) (Monsanto Chemical Co.).

(5) H. Weingarten, Abstract of Papers, American Chemical Society, 140th National Meeting, Chicago, Illinois, p. 56-Q.