

REACTION PRODUCTS OF PENTACHLOROBENZENE WITH POTASSIUM FLUORIDE IN DIMETHYL SULFOXIDE

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ABSTRACT.—Pentachlorobenzene was allowed to react with potassium fluoride in dimethyl sulfoxide at 180° C for 24 hours in a glass vessel. Seven compounds were identified by NMR-¹⁹F and infrared spectra: 2,4-dichloro-1,3,5-trifluorobenzene (7.3%), three difluorotrichlorobenzenes (30.3%), and three monofluorotetrachlorobenzenes (17.1%). No hydrogenated or rearranged products were detected in the reaction mixtures. Required reference compounds were synthesized by classical methods. Two new compounds, 1,3-difluoro-2,4,6-trichlorobenzene and 1,3-difluoro-4,5,6-trichlorobenzene, were synthesized.

Soon after studies on the replacement of chlorine by fluorine in chlorobenzenes by reaction with potassium fluoride in aprotic solvents were started in our laboratories, we recognized that certain chlorine atoms in 1,2,3,5-tetrachloro-, pentachloro-, and hexachlorobenzenes exhibited sufficient lability to undergo the chlorine-fluorine exchange reaction. Hexachlorobenzene was reported to give 1,3,5-trichlorotrifluorobenzene (Finger et al., 1957). Since then investigators have extended the exchange reaction to many other polychlorinated aromatic compounds.

Yakobson et al. (1966) treated pentachlorobenzene with potassium fluoride without a solvent at 260-390° C for 30 hours in a stainless steel autoclave and obtained a complex reaction mixture. Low yields of six polychlorofluorobenzenes and 3% of pentafluorobenzene were identified in the mixture. Several reductive dehalogenation and rearranged products were also observed. No literature data are available on the effects of less drastic conditions.

In our work, pentachlorobenzene was treated with potassium fluoride in dimethyl sulfoxide at 180° C for 24 hours. Distillation of the resulting mixture gave three fractions indicating different degrees of halogen replacement (See Table I). In general, nuclear magnetic resonance (NMR-¹⁹F) spectra were used to identify the principal components of the fractions. Fraction A was identified as 1,3-dichloro-2,4,6-trifluorobenzene (I). Fraction B was a mixture (approximate ratio 2:1:1) of 1,3-difluoro-2,4,5-trichlorobenzene (II), 1,3-difluoro-2,4,6-trichlorobenzene (III), and 1,3-difluoro-4,5,6-trichlorobenzene (IV). Fraction C was a mixture of approximately equal parts of 2,3,4,5-tetrachlorofluorobenzene (V), 2,3,4,6-tetrachlorofluorobenzene (VI), and 2,3,5,6-tetrachlorofluorobenzene (VII). No products resulting from reductive dehalogenation or rearrangement were isolated. In summary, the mild reaction conditions resulted in a 55% molar yield of a mixture consisting of three monofluoro isomers (C₆HCl₄F), three difluoro isomers (C₆HCl₃F₂), and one trifluorobenzene (C₆HCl₂F₃).

Studies of the reaction of potassium fluoride with hexachlorobenzene by Holbrook et al. (1966) indicated that the directive effect of fluorine is primarily meta, which we also observed in this study on pentachlorobenzene. In each di- and trifluorinated product (I-IV) the fluorine atoms are meta with respect to each other.

a quinoxaline derivative. Recrystallization from ethanol gave tan needles. Vacuum sublimation gave pure 2,3 - diphenyl - 5 - chloro - 6,8 - difluoroquinoxaline as a white solid, m.p. 179-180° C.

Anal. Calcd. for $C_{20}H_{11}ClF_2N_2$: C, 68.09; H, 3.14; N, 7.94. Found: C, 68.08; H, 3.25; N, 8.09.

2,6 - Dichloro - 3,5 - difluoronitrobenzene (XII). — A Sandmeyer reaction with cuprous chloride on 43.0 g (0.19 mole) of XI, utilizing nitrosyl sulfuric acid and 85% phosphoric acid in the diazotization, followed by steam distillation gave a 39.0 g (83%) yield of a crude yellow oil. Vacuum distillation gave pure XII, b.p. 114° C (20 mm), 228-229° C (microcapillary), m.p. 39-40° C. Literature datum: m.p. 42° C (Vorozhtsov et al., 1961a).

A mixed acid nitration of 1,5-dichloro-2,4-difluorobenzene with fuming sulfuric and fuming nitric acids also gave XII in a 68% yield, b.p. 116° C (20 mm). The melting point of a mixture of the two products failed to show a depression.

2,6 - Dichloro - 3,5 - difluoroaniline (XIII). — An iron reduction (Lukashevich and Voroshilova, 1935) of 33.0 g (0.145 mole) of XII gave 28.0 g (96.5%) of crude XIII. Recrystallization from ethanol, followed by vacuum sublimation, gave pure XIII, m.p. 77-78° C, b.p. 218-219° C (microcapillary). Literature datum: m.p. 73° C (Vorozhtsov et al., 1961b).

The acetyl derivative was prepared with acetyl chloride as acetylation failed to take place in acetic anhydride. Recrystallization from ethanol gave white needles, m.p. 183° C.

Anal. Calcd. for $C_8H_5Cl_2F_2NO$: N, 5.83. Found: N, 5.78.

1,3 - Difluoro - 4,5,6 - trichlorobenzene (IV). — A Sandmeyer reaction with cuprous chloride on 5.0 g (0.025 mole) of XIII gave IV as a low melt-

ing solid. Recrystallization from ethanol and methanol, followed by vacuum sublimation, gave pure IV, m.p. 50° C, b.p. 200° C.

Anal. Calcd. for $C_6HCl_3F_2$: C, 33.14; H, 0.46. Found: C, 33.15; H, 0.40.

Fraction C: Vacuum distillation gave a colorless oil, b.p. 114° C (8.5 mm), n_D^{20} 1.5738. The analysis indicated a composition of C_6HCl_4F .

Anal. Calcd. for C_6HCl_4F : C, 30.81; H, 0.43; Cl, 60.64; F, 8.12. Found: C, 31.08; H, 0.40; Cl, 60.42; F, 8.13.

The NMR- ^{19}F spectrum of the analytical sample showed it to be a mixture of V (Vorozhtov et al., 1961a), VI (Germano and Sechaud, 1954), and VII (Finger and Kruse, 1956) in equal amounts.

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40.00; H, 2.08. Found: C, 39.97; H, 2.24.

1,3 - Difluoro - 2,4,5 - trichlorobenzene (II). — A Sandmeyer reaction with cuprous chloride on 31.0 g (0.156 mole) of **IX** using nitrosyl sulfuric acid and 85% phosphoric acid in the diazotization gave, after vacuum distillation, 11.0 g (32.5%) of pure **II**, b.p. 91° C (45 mm), n_D^{20} 1.5310. Literature datum: n_D^{21} 1.5308 (Yakobson et al., 1966).

Anal. Calcd. for $C_6HCl_3F_2$: C, 33.14; H, 0.46; Cl, 48.92; F, 17.48. Found: C, 32.89; H, 0.63; Cl, 48.65; F, 17.24.

3 - Fluoro - 2,4,6 - trichloronitrobenzene (X). — A mixed acid nitration of 39.9 g (0.2 mole) of 2,4,6-trichlorofluorobenzene (Booth et al., 1935) at 50° C gave a 44.5 g (91.5%) yield of crude steam-distilled **X**. Vacuum distillation gave pure **X**, b.p. 91° C (2 mm), n_D^{25} 1.5585. Literature data: b.p. 216-220° C (atm), n_D^{20} 1.5680 (Kobrina and Yakobson, 1965).

3 - Fluoro - 2,4,6 - trichloroaniline. — A stannous chloride — hydrochloric acid reduction of 10.0 g (0.04 mole) of **X** followed by recrystallization from a mixture of benzene and low-boiling petroleum ether gave 4.3 g (71.5%) of crude product. Vacuum sublimation gave pure 3-fluoro-2,4,6-trichloroaniline, m.p. 69-69.5° C.

Anal. Calcd. for $C_6H_3Cl_3FN$: C, 33.60; H, 1.41; Cl, 49.60; N, 6.53. Found: C, 33.86; H, 1.54; Cl, 49.56; N, 6.67.

The acetyl derivative was recrystallized from benzene and vacuum sublimed, m.p. 193-194° C (corr).

Anal. Calcd. for $C_8H_5Cl_3FNO$: C, 37.46; H, 1.96. Found: C, 37.53; H, 2.11.

1,3 - Difluoro - 2,4,6 - trichlorobenzene (III). — A mixture of 15.0 g (0.062 mole) of **X**, 17.8 g (0.31 mole) of KF, and 30 ml of DMSO was

heated to 170° C for a period of 2 hours. Evolution of nitrogen oxide fumes was first noted when the temperature reached 150° C. After it cooled, the mixture was poured into water. Steam distillation, followed by vacuum distillation, gave a 2.0 g yield (15%) of pure **III**, b.p. 104° C (18 mm), n_D^{20} 1.5290.

Anal. Calcd. for $C_6HCl_3F_2$: C, 33.14; H, 0.46; Cl, 48.92; F, 17.48. Found: C, 33.36; H, 0.72; Cl, 48.70; F, 17.39.

3 - Chloro - 4,6 - difluoro - 2 - nitroaniline (XI). — To a well stirred slurry of 36 ml of glacial acetic acid and 36.5 g (0.18 mole) of 3-chloro-4,6-difluoroacetanilide (Finger and Oesterling, 1956) was added 52 ml of concentrated sulfuric acid at 30-40° C. A mixture containing 21 ml (0.33 mole) of 70% nitric acid and an equal volume of concentrated sulfuric acid was added in 15 minutes. The temperature was allowed to rise naturally to 60° C and stirring was continued for 2 hours. The mixture was poured into ice and filtered. The crude nitroacetanilide was hydrolyzed to the nitroamine by heating the mixture with 60 ml of concentrated sulfuric acid at steam bath temperature for 2 hours. The mixture was poured into ice. Recrystallization from 3-fluorobenzotrifluoride and from ethanol followed by a vacuum sublimation gave pure **XI** as orange-yellow needles, m.p. 82-82.5° C.

Anal. Calcd. for $C_{10}H_7ClF_2N_2$: C, 34.55; H, 1.45; N, 13.43. Found: C, 34.76; H, 1.39; N, 13.27.

The acetyl derivative was recrystallized from ethanol to give white needles, m.p. 184° C.

Anal. Calcd. for $C_8H_5ClF_2NO_3$: N, 11.17. Found: N, 11.15.

To prove the adjacency of the nitro and amino groups, the nitroamine was converted to the diamine and a subsequent reaction with benzil gave

EXPERIMENTAL

The potassium fluoride used in this experiment was dried at 120° C for 24 hours and quickly powdered in a warm mortar.

Melting and boiling points are uncorrected.

The NMR-¹⁹F spectra were run using a Varian DP-60 instrument. Interpretations of the spectra were made according to Gutowsky et al. (1952) using fluorobenzene as an external standard.

Fluorination of Pentachlorobenzene. — A mixture of 33.5 g (0.137 mole) of pentachlorobenzene, 58.0 g (1 mole) of finely ground potassium fluoride, and 100 ml of dimethyl sulfoxide (DMSO) was dried by azeotropic distillation with benzene, and then stirred and heated at 180° C for 24 hours. The crude product was diluted with water and steam distilled. Vacuum distillation gave three fractions: **A**, 2.0 g (7.3%), b.p. 61–63° C (23 mm), n_d^{20} 1.4897; **B**, 9.0 g (30.3%), b.p. 61–83° C (17 mm), n_d^{20} 1.5300; and **C**, 5.5 g (17.1%), b.p. 81–199° C (17 mm), n_d^{20} 1.5661. Percentages were calculated on the basis of molar yields of products identified below. **Fraction A:** Redistillation gave pure **I**, b.p. 79–82° C (42 mm), n_d^{20} 1.4870.

Anal. Calcd. for $C_6HCl_2F_3$: C, 35.85; H, 0.50; Cl, 35.28; F, 28.36. Found: C, 35.67; H, 0.71; Cl, 35.53; F, 28.50.

2,4 - Dichloro - 3,5 - difluoronitrobenzene (VIII). — A Sandmeyer reaction with cuprous chloride on 3-chloro - 2,4 - difluoro - 6 - nitroaniline (Finger et al., 1956), utilizing nitrosyl sulfuric acid and 85% phosphoric acid in the diazotization, and a subsequent steam distillation gave a 66% yield of a yellow oil. Vacuum distillation gave pure **VIII**, b.p. 113° C ((12.5 mm)).

Anal. Calcd. for $C_6HCl_2F_2NO_2$: C, 31.61; H, 0.44; Cl, 31.10; N, 6.14.

Found: C, 31.80; H, 0.50; Cl, 30.85; N, 6.14.

1,3 - Dichloro - 2,4,6 - trifluorobenzene (I). — A mixture of 20.0 g (0.09 mole) of **VIII**, 11.6 g (0.2 mole) of KF, and 130 ml of DMSO was dried by azeotropic distillation with benzene and then heated at 135° C for 45 minutes until the evolution of the oxides of nitrogen had ceased. The temperature of the mixture was gradually increased to 180° C and then cooled. Steam distillation gave 6.0 g (33%) of a crude yellow oil. Distillation gave pure **I**, b.p. 160° C, n_d^{20} 1.4865. This product was found to be identical with that produced in the "halogen-exchange" reaction when their infrared spectra were compared. Literature data: b.p. 161.5–162° C, n_d^{20} 1.4863 (Finger et al., 1951). **Fraction B:** Purification by vacuum distillation gave a colorless oil, b.p. 89° C (15mm), n_d^{20} 1.5298.

Anal. Calcd. for $C_6HCl_2F_2$: C, 33.14; H, 0.46; Cl, 48.92; F, 17.48. Found: C, 33.06; H, 0.52; Cl, 48.68; F, 17.66.

The NMR-¹⁹F spectrum indicated that the sample was a mixture of the three difluoro isomers **II**, **III**, and **IV** (approximate ratio 2:1:1, respectively).

2,4 - Dichloro - 3,5 - difluoroaniline (IX). — A stannous chloride — hydrochloric acid reduction of 32.0 g (0.14 mole) of **VIII** gave a 25.0 g (90%) crude yield of **IX**. Recrystallization from a mixture of benzene and low-boiling petroleum ether, followed by vacuum sublimation, gave pure **IX**, m.p. 65.6–66.5° C.

Anal. Calcd. for $C_6H_2Cl_2F_2N$: C, 36.39; H, 1.53; Cl, 35.81; N, 7.07. Found: C, 36.21; H, 1.63; Cl, 36.09; N, 6.90.

The acetyl derivative was recrystallized from benzene, m.p. 118.5–119° C.

Anal. Calcd. for $C_8H_5Cl_2F_2NO$: C,

TABLE 1.—Fluorination of Pentachlorobenzene

DISTILLATION FRACTION	A		B		C		
FRACTION b.p. ($^{\circ}\text{C}/\text{mm}$)	79-82/42		89/15		114/8.5		
COMPONENTS b.p. ($^{\circ}\text{C}/\text{mm}$)	160/atm	91/45	104/18	200/atm	75/0.7	---	---
FRACTION n_D^{20}	1.4870		1.5298		1.5738		
COMPONENTS n_D^{20}	1.4865	1.5310	1.5290	---	---	---	---
COMPONENTS m.p. ($^{\circ}\text{C}$)	---	---	---	50	65-66 ^{a/}	17 ^{b/}	71.5-72.5 ^{c/}
YIELD OF FRACTION (%)	7.3		30.3		17.1		
DISTRIBUTION (%)	100	50.0	25.0	25.0	33.3	33.3	33.3

^{a/} Lit. m.p. 63-64 $^{\circ}\text{C}$ (Vorozhtsov et al., 1961a).^{b/} Germano and Sechaud, 1954.^{c/} Finger and Kruse, 1956.

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