

346. *Aromatic Polyfluoro-compounds. Part XVI.¹ Nucleophilic Substitution in Perfluoro(ethylbenzene).*

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Perfluoro(ethylbenzene) has been treated with hydrazine, ammonia, lithium aluminium hydride, sodium methoxide, and methyl-lithium, to give, respectively, 2,3,5,6-tetrafluoro-4-(perfluoroethyl)phenylhydrazine, 2,3,5,6-tetrafluoro-4-(perfluoroethyl)aniline, 4*H*-nonafluoro(ethylbenzene), 2,3,5,6-tetrafluoro-4-(perfluoroethyl)anisole, and 2,3,5,6-tetrafluoro-4-(perfluoroethyl)toluene. 2,3,5,6-Tetrafluoro-4-(perfluoroethyl)phenylhydrazine has been converted into 2,3,5,6-tetrafluoro-4-(perfluoroethyl)aniline and into 4*H*-nonafluoro(ethylbenzene).

PERFLUORO(ETHYLBENZENE) can be prepared by the defluorination of perfluoro(ethylcyclohexane) over heated iron ² which gives, under optimum conditions, approximately 15% conversion into perfluoro(ethylbenzene), in terms of starting material consumed, together with a small amount of octafluorostyrene, which may also be produced by the further defluorination of perfluoro(ethylbenzene).³

¹ Part XV, Burdon, Damodaran, and Tatlow, *J.*, 1964, 763.

² Gething, Patrick, Stacey, and Tatlow, *Nature*, 1959, **183**, 588.

³ Letchford, Patrick, Stacey, and Tatlow, *Chem. and Ind.*, 1962, 1472.

Perfluoro(ethylbenzene) reacted readily with a number of nucleophilic reagents, as do other highly fluorinated aromatic compounds, and the products have been shown to contain the new substituent *para* to the perfluoroethyl group.

Reaction of perfluoro(ethylbenzene) with hydrazine gave an ethylphenylhydrazine, which showed a nuclear magnetic resonance (n.m.r.) spectrum consistent with the structure 2,3,5,6-tetrafluoro-4-(perfluoroethyl)phenylhydrazine. This compound reacted with Fehling's solution to give 4*H*-nonafluoro(ethylbenzene), identical with the product of reaction of lithium aluminium hydride with perfluoro(ethylbenzene). Reduction of 2,3,5,6-tetrafluoro-4-(perfluoroethyl)phenylhydrazine with zinc and acetic acid gave 2,3,5,6-tetrafluoro-4-(perfluoroethyl)aniline, which was also obtained by reaction of perfluoro(ethylbenzene) with aqueous ammonia. 2,3,5,6-Tetrafluoro-4-(perfluoroethyl)-aniline was characterised as its *N*-acetyl derivative.

Reaction of perfluoro(ethylbenzene) with methyl-lithium yielded a tetrafluoro(methyl)-(perfluoroethyl) benzene. This was fluorinated in a small reactor packed with cobalt trifluoride, to yield a perfluoroethyl(methylcyclohexane) identical in its infrared (i.r.) spectrum with the product of fluorination of *p*-ethyltoluene. Since, in fluorination reactions of the type used, there is no evidence of migration of substituent alkyl groups, this sequence of reactions proves that the product of the reaction of methyl-lithium with perfluoro(ethylbenzene) must be 2,3,5,6-tetrafluoro-4-(perfluoroethyl)toluene. Thus, the perfluoroethyl group directs nucleophilic attack by ammonia, hydrazine, lithium aluminium hydride, and methyl-lithium, to the *para*-position.

The oxidation of 2,3,5,6-tetrafluoro-4-(perfluoroethyl)toluene to 2,3,5,6-tetrafluoro-4-(perfluoroethyl)benzoic acid was attempted with nitric acid and with potassium permanganate, but both were unsuccessful. This is in contrast to the successful oxidation of 2,3,5,6-tetrachloro-*p*-xylene to tetrachloroterephthalic acid,⁴ but parallels experience with 2,3,5,6-tetrafluoro-*p*-xylene⁵ and 1,3,4,5,6,7,8-heptafluoro-2-methylnaphthalene.⁶

Chlorination of 2,3,5,6-tetrafluoro-4-(perfluoroethyl)toluene gave a mixture of products which was not completely separated. One fraction, suspected to contain a mixture of chloro-, dichloro-, and trichloro-methyl compounds, was treated with alkaline potassium permanganate for seven days, but only starting material was recovered.

2,3,5,6-Tetrafluoro-4-(perfluoroethyl)anisole was obtained by the reaction of sodium methoxide in methanol with perfluoro(ethylbenzene), and its structure was confirmed by n.m.r. spectroscopy. A small amount of a higher-boiling substance, which had the correct analysis for a trifluoro(dimethoxy)(perfluoroethyl) benzene, was also isolated from the reaction product. Reaction of perfluoro(ethylbenzene) with sodium hydroxide or potassium hydroxide, under a variety of conditions, did not yield the desired phenol. Using potassium hydroxide in *t*-butyl alcohol, a high-boiling viscous oil, with the correct analysis for $[C_8F_8O]_n$, was obtained. It is probable that this material is a substituted polyphenylene oxide, formed by reaction of substituted phenol with an appropriate nucleophile. The possibility of such a reaction is demonstrated by the observed formation of a dimethoxy-compound in the reaction of perfluoro(ethylbenzene) with sodium methoxide. Attempts to prepare 2,3,5,6-tetrafluoro-4-(perfluoroethyl)phenol from 2,3,5,6-tetrafluoro-4-(perfluoroethyl)anisole using aluminium chloride, a reagent which was successful in the preparation of pentafluorophenol from pentafluoroanisole,⁷ failed.

The nucleophilic reactions described for perfluoro(ethylbenzene) have in common the feature that the reagent preferentially attacks the position *para* to the perfluoroethyl group. As in other cases reported, the preferred position of nucleophilic attack is determined by the fluoro-aromatic compound rather than by the attacking reagent. It

⁴ Rupp, *Ber.*, 1896, **29**, 1628.

⁵ Barbour, Buxton, Coe, Stephens, and Tatlow, *J.*, 1961, 808.

⁶ Gething, Patrick, and Tatlow, *J.*, 1962, 186.

⁷ Forbes, Richardson, Stacey, and Tatlow, *Chem. and Ind.*, 1958, 630.

is not surprising that, since the preferred position for attack is determined by the electronic influence of the substituent, the perfluoroethyl group studied in the present work should resemble the trifluoromethyl group.

EXPERIMENTAL

N.m.r. measurements were carried out on a Mullard SL 44 Mark 1 instrument at 30·107 Mc./sec.

2,3,5,6-Tetrafluoro-4-(perfluoroethyl)phenylhydrazine.—Perfluoro(ethylbenzene) (8·5 g.), hydrazine hydrate (100% w/w; 3·0 g., 1·6 moles), and ethanol (40 ml.) were refluxed for 5 hr., and the mixture was poured into water (200 ml.). A reddish solid, m. p. 79—80° (7·1 g.), which precipitated was washed with water, and recrystallised from light petroleum (b. p. 40—60°) to give pale yellow crystals of the *phenylhydrazine* (5·2 g.), m. p. 84° (Found: C, 32·1; H, 1·0. C₈H₇F₉N₂ requires C, 32·2; H, 1·0%). The ¹⁹F n.m.r. spectrum showed four multiplets similar to those found in the spectrum of the tetrafluoro-4-(perfluoroethyl)anisole (see below). These correspond to the fluorine atoms of the CF₃ and CF₂ groups, and to the electronically different fluorine atoms on the benzene nucleus.

Benzaldehyde 2,3,5,6-Tetrafluoro-4-(perfluoroethyl)phenylhydrazone.—The phenylhydrazine (2·5 g.) was dissolved in ethanol (30 ml.), and concentrated sulphuric acid (0·5 ml.) and benzaldehyde (1·0 g.) were added dropwise. The mixture was heated under reflux for 1 hr., and water was added to the cooled solution. The precipitate was filtered off, boiled with water, and filtered hot to remove any benzoic acid. Recrystallisation of the precipitate from light petroleum (b. p. 60—80°) gave the *phenylhydrazone* (2·4 g.), m. p. 161—162° (Found: C, 46·3; H, 1·6. C₁₅H₇F₉N₂ requires C, 46·6; H, 1·8%).

4H-Nonafluoro(ethylbenzene) from 2,3,5,6-Tetrafluoro-4-(perfluoroethyl)phenylhydrazine.—The phenylhydrazine (1·3 g.) was heated under reflux with Fehling's solution [solution A (50 ml.); solution B (50 ml.)] for 30 min. The mixture was then distilled and the first 50 ml. of distillate collected. Two layers separated out, and the lower fluorocarbon layer (0·6 g.) was distilled under vacuum, from phosphorus pentoxide, to give pure 2,3,5,6-tetrafluoro-4-(perfluoroethylbenzene) (0·5 g.), b. p. 124° (Found: C, 35·8; H, 0·4. C₈HF₉ requires C, 35·8; H, 0·4%).

4H-Nonafluoro(ethylbenzene) from Perfluoro(ethylbenzene).—Perfluoro(ethylbenzene) (3·0 g.) was refluxed for 4 days with a slurry of lithium aluminium hydride (1·0 g.) in dry ether (10 ml.). Water was then added dropwise to decompose the complex formed, and dilute sulphuric acid (15 ml.) added. The non-aqueous layer was separated and dried (MgSO₄). Gas chromatography showed it to consist of three components; the retention times of two of these corresponded to ether and perfluoro(ethylbenzene). The products were separated by preparative gas chromatography to give ether, perfluoro(ethylbenzene) (0·1 g.), 4H-nonafluoro(ethylbenzene) (1·25 g.), identical (i.r. spectrum) with the product obtained above.

Reduction of Benzaldehyde 2,3,5,6-Tetrafluoro-4-(perfluoroethyl)phenylhydrazone.—A stirred mixture of the phenylhydrazone (2·1 g.), zinc (4·9 g.), and glacial acetic acid (30 ml.) was heated under reflux for 4½ hr. The mixture was poured into water, and steam-distilled to give about 250 ml. of aqueous distillate, which was made alkaline and extracted with ether (3 × 50 ml.). The extracts were dried (MgSO₄), and the ether was distilled off, to leave a brownish liquid which was distilled, to give 2,3,5,6-tetrafluoro-4-(perfluoroethyl)aniline (0·75 g.), b. p. 58—60°/12 mm. The amine had an i.r. spectrum identical with that of the product of the reaction of aqueous ammonia with perfluoro(ethylbenzene).

2,3,5,6-Tetrafluoro-4-(perfluoroethyl)aniline from Perfluoro(ethylbenzene).—Perfluoro(ethylbenzene) (2·9 g.) and ammonia (*d* 0·88; 2·5 ml.) were heated for 20 hr. in a sealed tube at 130°. The dark brown viscous product was poured into water (50 ml.) and the mixture separated into two layers. The whole was extracted with ether (4 × 50 ml.) and the extracts were dried (MgSO₄). The ether was distilled off and the residual liquid was fractionally distilled to give the pure *fluorinated aniline* (1·8 g.), b. p. 78—80°/15 mm. (Found: C, 34·1; H, 0·7. C₈H₂F₉N requires C, 33·9; H, 0·7%).

The amine (187 mg.), acetic anhydride (150 mg., 2·2 moles), and two drops of concentrated sulphuric acid were refluxed for 2 min. Water (1 ml.) was added and the mixture boiled to remove the excess of acetic anhydride. The dark brown precipitate was filtered off and sublimed (120°/0·01 mm.) to give a white solid (107 mg.), m. p. 136—139°, which was

recrystallised from aqueous ethanol to give the pure *N*-acetyl derivative (96 mg.), m. p. 139—140° (Found: C, 37.0; H, 1.4. $C_{10}H_4F_9NO$ requires C, 36.9; H, 1.2%).

2,3,5,6-Tetrafluoro-4-(perfluoroethyl)toluene.—Dry methyl iodide (25 ml.; 60.0 g.) in ether (75 ml.) was added dropwise to small pieces of lithium (6.9 g.) in ether (100 ml.), at such a rate that the ether refluxed. The excess of lithium (2.2 g.) was removed by filtration through glass wool, and the solution was used immediately.

An ethereal solution of methyl-lithium (1.2 g. in 40 ml.) was added to a stirred mixture of perfluoro(ethylbenzene) (15 g.) in sodium-dried ether (50 ml.), at such a rate that the ether refluxed. After the addition was complete, the solution was heated under reflux for 1 hr. 4*N*-Sulphuric acid (30 ml.) was added to decompose the excess of methyl-lithium, and the ether layer was separated off, washed with water, and dried ($MgSO_4$). The ether was removed by distillation through a 6 in. glass column packed with glass helices and the residue distilled from phosphorus pentoxide to give (i) a mixture (A) of perfluoro(ethylbenzene) and 2,3,5,6-tetrafluoro-4-(perfluoroethyl)toluene (6.7 g.), and (ii) the pure fluorotoluene (4.4 g.), b. p. 149—151° (Found: C, 38.5; H, 1.3. $C_9H_3F_9$ requires C, 38.3; H, 1.1%).

The mixture (A) was separated by preparative gas chromatography, to give perfluoro(ethylbenzene) (1.8 g.) and the fluorotoluene (3.05 g.).

Fluorination of 2,3,5,6-Tetrafluoro-4-(perfluoroethyl)toluene.—The fluorotoluene (0.9 g.) was added dropwise to a small static cobalt trifluoride reactor at 310°, during 1 hr. Nitrogen (2 l./hr.) was then passed through the reactor for 1 hr. The product (0.8 g.) was collected in a Polythene beaker under ice-water, separated from the aqueous layer, and distilled from phosphorus pentoxide, to give perfluoro-(1-ethyl-4-methylcyclohexane) (0.8 g.), b. p. 126° (Found: C, 24.3; F, 76.5. C_9F_{18} requires C, 24.0; F, 76.0%).

Fluorination of *p*-Ethyltoluene.—*p*-Ethyltoluene (prepared by the reaction of the Grignard reagent from *p*-bromotoluene with diethyl sulphate) (2.5 g.) was added dropwise to a small static cobalt trifluoride reactor during 1 hr. Nitrogen (2 l./hr.) was then passed through the reactor, and the products (2.3 g.) were collected under ice-water in a Polythene beaker. Gas chromatography showed the product to consist of three components; these were separated by preparative gas chromatography, to give perfluoro(methylcyclohexane) (a trace), perfluoro(ethylcyclohexane) (a trace), and perfluoro-(1-ethyl-4-methylcyclohexane) (1.3 g.). This compound had an i.r. spectrum identical with that of the product of the fluorination of 2,3,5,6-tetrafluoro-4-(perfluoroethyl)toluene.

2,3,5,6-Tetrafluoro-4-(perfluoroethyl)anisole.—A methanolic solution of sodium methoxide was prepared by the addition of small pieces of sodium (0.7 g.) to dry methanol (50 ml.). Perfluoro(ethylbenzene) (6.5 g.) was added and the solution refluxed for 4 hr. When cool, the mixture was poured into water (400 ml.). Two layers formed. The lower fluorocarbon layer (5.3 g.) was separated, washed with water, and distilled from phosphorus pentoxide, to give the anisole (4.5 g.), b. p. 154° (Found: C, 36.0; H, 1.5. $C_9H_3F_9O_3$ requires C, 36.2; H, 1.0%).

The ^{19}F n.m.r. spectrum showed four multiplets, at 9.5, 33.9, 66.4, and 94.1 p.p.m., relative to trifluoroacetic acid, corresponding, respectively, to the fluorine atoms of the CF_3 and CF_2 groups and to the electronically different fluorine atoms on the benzene ring.

The residue from this distillation was redistilled, to give a trifluoro(dimethoxy)(perfluoroethyl)benzene, b. p. 181° (0.4 g.) (Found: C, 38.3; H, 1.8. $C_{10}H_8F_8O_2$ requires C, 38.7; H, 1.9%).

Reaction of Potassium Hydroxide in *t*-Butyl Alcohol with Perfluoro(ethylbenzene).—Perfluoro(ethylbenzene) (2.1 g.) was heated under reflux with potassium hydroxide (1.1 g.) in *t*-butyl alcohol (20 ml.) for 4½ hr., water (50 ml.) was added, and the *t*-butyl alcohol distilled off. The aqueous solution was extracted with ether (3 × 50 ml.), acidified with sulphuric acid, and continuously extracted with ether for 10 hr. The dried acidic ether extracts left no residue when concentrated. The dried ($MgSO_4$) alkaline ether extracts gave a viscous pale yellow polymeric oil (1.8 g.) which did not distil at 250°/7 mm. (Found: C, 37.2; H, 0.0. Calc. for $[C_8F_8O]_n$: C, 36.4; H, 0.0%).

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