

REACTION OF TRICHLORO-2-THIENYLLITHIUM WITH HEXAFLUOROBENZENE; 1,2,4,5-TETRAKIS (TRICHLORO-2-THIENYL) DIFLUOROBENZENE

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SUMMARY

Trichloro-2-thienyllithium reacts with hexafluorobenzene in THF to give tetrakis (trichloro-2-thienyl)difluorobenzene in good yield. The corresponding Grignard reagent, and the lithium reagent in ether, give lower yields and require higher temperature and longer times for reaction. Fluorobenzene and pentafluorobenzene do not undergo substitution under comparable conditions.

INTRODUCTION

Nucleophilic substitution in hexafluorobenzene is well documented. The reaction has been used to prepare ethers^{1,2}, amines³⁻⁶, thiols⁷, silanes^{8,9}, alkyl-^{10,11}, alkenyl-¹², alkynyl-¹³ and aryl-substituted¹⁴ compounds. The substitution reaction is the primary side-reaction in attempts to prepare pentafluorophenylmetallic compounds directly from hexafluorobenzene¹⁵. Under suitable conditions di- and, in two cases⁵⁻⁷, tetra-substituted compounds are produced.

RESULTS AND DISCUSSION

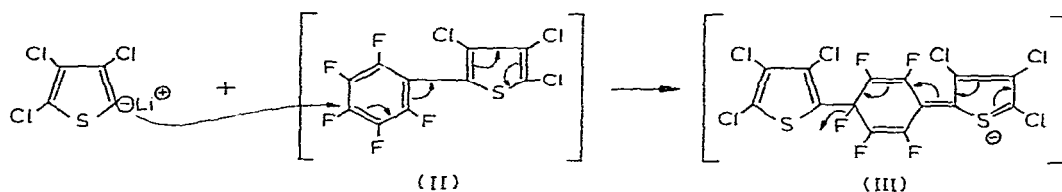
We have observed that trichloro-2-thienyllithium in THF reacts readily under moderate conditions with hexafluorobenzene to give tetrakis(trichloro-2-thienyl)difluorobenzene (I) in high yields.



There was no evidence for the formation of mono-, di- or tri-substituted product under these conditions even when hexafluorobenzene was in excess. The

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above reaction apparently involves "aromatic nucleophilic substitution". The electron-withdrawing character of the trichloro-2-thienyl group in the intermediate mono-substituted compound (II) makes the *ortho*- and *para*-positions more electron deficient and consequently more susceptible to further nucleophilic attack¹⁶. The trichloro-2-thienyl group may stabilize the "intermediate complex" (such as III) by dispersing the negative charge through resonance and thus accelerate the rate of further substitution:



The reaction stops apparently due to steric hindrance involved in penta- or hexa-substituted products. We believe that compound I is 1,2,4,5-tetrakis(trichloro-2-thienyl)difluorobenzene on the basis of dipole-moment measurements and steric hindrance involved in other arrangements of substituents. The tetra-substituted compounds where two fluorines are *ortho* or *meta* will be more sterically strained than the one where fluorines are *para*-substituted (I). The *para*-arrangement is further supported on the basis of the tendency toward *para*-substitution in similar reactions³⁻¹⁵.

Trichloro-2-thienylmagnesium halide did not react with hexafluorobenzene under similar conditions. However, reaction occurs at room temperature and over a prolonged period to give a lower yield (25%) of the tetra-substituted compound (I). This could be attributed to the decreased nucleophilicity of the Grignard reagent compared to the corresponding organolithium derivative. A similar observation has been made involving PhN(Me)MgX and PhN(Me)Li types in reaction with hexafluorobenzene⁶.

The decreased reactivity of trichloro-2-thienyllithium in ether is in accord with the less polar nature of the solvent which would tend to decrease the nucleophilic character of the lithium reagent. Similar effects have been observed with dimethoxyethane¹³ as the solvent when compared to ether.

The reaction of pentafluorobenzene with trichloro-2-thienyllithium affords pentafluorophenyllithium rather than the substituted product. Apparently, the metalation reaction is faster than substitution and this has been observed in other systems^{13,18}.

The failure of fluorobenzene to react may be attributed to the absence of activating effects of the other fluorine atoms present in hexafluorobenzene. There was no indication of metalation in fluorobenzene although such a reaction does occur with *n*-butyllithium¹⁷.

EXPERIMENTAL

All reactions were performed under dry oxygen-free nitrogen in glass ware which was dried at 120°, assembled while hot, and flushed with dry nitrogen while

cooling. THF was dried over sodium and distilled from sodium benzophenone ketyl. Tetrachlorothiophene (Hooker Chemical Co.), hexafluorobenzene (Whittaker Corporation), t-butyl- and n-butyllithium (Foote Mineral Co.) were used as received. Magnesium turnings were from Mallinckrodt Chemical Works.

IR spectra were taken of the compound in KBr pellets on a Beckman IR-12. The mass spectrum was scanned on an Atlas CH4. VPC analyses were made on an F&M Model 500 using a $4\frac{1}{2}' \times 1/4''$ column of Silicone Gum Rubber (15% on Chromosorb W). DTA was run on a Du Pont Differential Thermal Analyzer, Model 900.

Reaction of trichloro-2-thienyllithium with hexafluorobenzene in THF

Trichloro-2-thienyllithium was prepared in THF from t-BuLi and tetrachlorothiophene according to the reported procedure¹⁹.

(A) *1/1 molar ratio of C_6F_6 and $2-C_4Cl_3SLi$* . To trichloro-2-thienyllithium (0.05 mole) in 100 ml THF at -78° was added 9.3 g (0.05 mole) C_6F_6 in 100 ml THF during 20 min. The reaction was stirred overnight (14 h). Color Test I²⁰ was negative, and a precipitate was noticed in the flask. The reaction mixture was warmed to room temperature and hydrolyzed. The aqueous and organic layers were separated (facilitated by the addition of 100 ml hexane) and the light tan precipitate was filtered to give 9.05 g of crude material m.p. $300-315^\circ$. An additional 0.2 g was recovered from the solvents. Recrystallization from chloroform gave 8.25 g (78%) of material. It was noticed that although attractive crystals grew in the chloroform solutions, these became white powders when allowed to dry at room temperature, m.p. $337-338^\circ$ (oil bath); $344-345^\circ$ (Meltemp block). (Found: Cl, 49.50; F, 4.68; S, 15.04%; $C_{22}Cl_{12}: F_2S_4$ calcd: Cl, 49.70; F, 4.44; S, 14.98%). The mass spectrum of the compound is complex but shows a broad peak centered at 856 (M^+ , calc. 855.9), at 820 ($(M-Cl)^+$, calc. 820.4), and at 785 ($(M-2Cl)^+$, calc. 784.9). Peaks centered at ca. 750, 714 and 679 correspond to stepwise loss of at least 5 Cl atoms. The pattern gets more complicated until at below ca. 300 only minor peaks occur. The IR spectrum of the compound shows no peaks above 1540 cm^{-1} . The following are the important peaks (in cm^{-1}): 1475 (s); 1425 (s); 1325 (s); 1040 (m); 1015 (m); 920 (s); 890 (sh); 780 (vs); 620 (w); 550 (w); 475 (w); 450 (w); 410 (vw).

A DTA thermogram in air of ca. 10 mg of the material showed a melting endotherm at $335-340^\circ$. No additional peaks were noted until decomposition began at 480° . A broad exothermic peak was noticed between $480-540^\circ$.

(B) *1/4 molar ratio of C_6F_6 and $2-C_4Cl_3SLi$* . To trichloro-2-thienyllithium (0.1 mole) in THF at -78° was added 4.8 g (0.025 mole) of C_6F_6 . The reaction was stirred 20 h and allowed to warm to room temperature. VPC showed only a very small amount of unreacted C_6F_6 . Work-up as before yielded 17.1 g (80%) of white product, m.p. $342-343^\circ$ (Meltemp block). Recrystallization of a portion of this material gave a sample melting at $344-345^\circ$. The IR spectrum was identical to that of the previously described sample.

Reaction of trichloro-2-thienyllithium with hexafluorobenzene in ether

To trichloro-2-thienyllithium (0.05 mole) in 100 ml ether was added at room temperature, C_6F_6 (9.3 g; 0.05 mole). After 5 h there was much precipitate but Color Test I²⁰ was still positive. After 20 h the Color Test was positive, but was negative

after 48 h. Work-up gave 5.1 g of crude material. Recrystallization yielded 4.7 g (44%) of compound (I) m.p. 335–337°.

Reaction of trichloro-2-thienylmagnesium halide with hexafluorobenzene in THF

Trichloro-2-thienylmagnesium halide (0.05 mole scale) was prepared by the reported "entrainment" procedure²¹. The solution was then cooled to -78° and hexafluorobenzene 2.32 g (0.0125 mole) was added. The reaction was monitored by VPC (disappearance of C_6F_6). The temperature of the reaction was slowly increased to 0° over a period of 35 h with no reaction indicated. After 72 h at room temperature ca. 40–50% of the C_6F_6 had been consumed. Color Test I was negative. Work-up gave 5.8 g of crude product. Recrystallization yielded 2.7 g (25%) of compound (I), m.p. and mixed m.p. 343–345° (Meltemp block). The IR spectrum was superimposable with that of the authenticated sample.

Trichloro-2-thienyllithium with fluorobenzene in THF

To trichloro-2-thienyllithium (0.05 mole) in THF was added 4.8 g (0.05 mole) of C_6H_5F . After 14 h at -78° there was no evidence of a reaction (VPC). The mixture was allowed to come to room temperature and was stirred for 10 days. VPC (subsequent to hydrolysis) showed no $C_4Cl_3S-C_6H_5$ or products other than C_4Cl_3HS and C_6H_5F .

*Dipole Measurement**

Microwave absorption results at 25 cm wavelength (1.2 GHz) on a solution (0.0012 mole fraction) in CCl_4 suggest that tetrakis(trichloro-2-thienyl)difluorobenzene is at most only slightly polar. It is therefore definitely not the *o*-difluoro derivative. Results at 1 cm and 2 mm (24.4 and 135 GHz) suggest the possibility of the *m*-difluoro compound but based on dispersion data for many similar systems the *para* structure seems the most likely.

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