

FLUORINATED ALLENES AND ALKYNES

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Summary: Perfluoroalkyl copper and perfluoroalkylene dicopper reagents couple with propargyl bromide to give the perfluoroallenes and perfluorodiallenes with 100% regioselectivity, but gave perfluoroallene/perfluoroalkyne mixtures or pure perfluoroalkynes with trialkylsilyl propargyl bromides.

The perfluoroalkyl organometallics such as R_f -Li and R_f -MgX, have limited utility as reagents for introducing the perfluoroalkyl group into organic molecules due to their low thermal stability². Perfluoroalkyl zinc³ and perfluoroalkyl copper⁴ are more useful for this purpose. The latter is especially useful for the preparation of fluoroalkyl substituted aromatic compounds by the coupling reaction with aromatic iodides and bromides⁴.

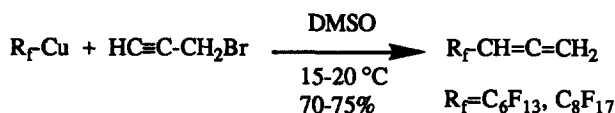
There are few reports about the couplings of perfluoroalkyl metals with aliphatic halides. Usually, the unactivated alkyl halides (except some simple substrates, such as MeI) are not reactive toward the perfluoroalkyl metal reagents, but vinyl or allyl halides react with perfluoroalkyl zinc to form the coupled products in the presence of Pd catalyst⁵. Similar results have been observed for perfluoroalkyl coppers but the extra catalyst is generally not needed⁶.

The coupling reaction between perfluoroalkyl metals and a propargyl system is also relatively unknown. Burton and his coworkers recently described that $(CF_2H)_2Cd$, $(CF_2H)Cu$ and some perfluoroalkyl coppers reacted with propargyl halides to give allenes as the products in most cases, but in few cases the mixture of allene and alkyne were obtained. For example, CF_2HMX reacted with 1-bromo-2-butyne to yield a 78:22 allene:alkyne mixture and C_3F_7Cu reacted with the same reagent to give a 94:6 allene:alkyne product.^{7,8}

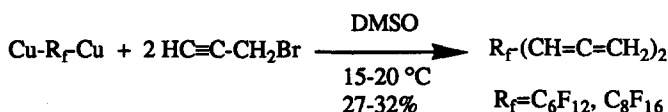
In addition, Coe and his coworker reported that the reaction of perfluoro-n-heptyl copper with propargyl bromide at 110 °C was violently exothermic and afforded, after a difficult workup (including a minor explosion), only 10% yield of the 1-(perfluoro-n-heptyl)-1,2-propadiene product⁹.

We now would like to report an improved, efficient synthesis of the perfluoroalkyl allenes starting from perfluoroalkyl copper reagents. Perfluoroalkyl copper was prepared from perfluoroalkyl iodide with 2 mole equivalents of activated Cu powder¹⁰ in DMSO⁴ at 100-120 °C. Then the R_fCu reagent

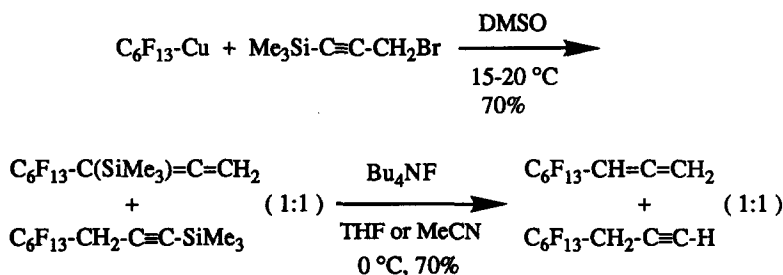
was cooled to 15 to 20 °C and the propargyl bromide was added slowly at a rate that kept the pot temperature below 20 °C. The product was then isolated quickly from the reaction mixture¹¹. After further purification, the yield were in the 70-75% range. The products were pure perfluoroalkyl allenes, none of the perfluoroalkyne was detected.



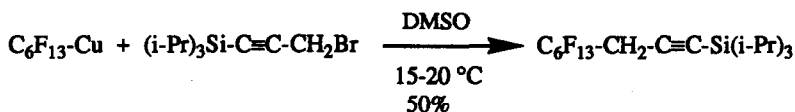
The reaction could be further extended to the preparation of perfluoroalkylene diallenes. Reaction of the bisperfluoroalkylene dicopper $\text{Cu-R}_f\text{-Cu}$ (prepared from diiodoperfluoroalkanes) with propargyl bromide afforded the desired perfluoroallenes, again with complete regioselectivity, but in lower yields.



In order to study the influence of the steric factors in these coupling reactions, the reactions between perfluoroalkyl copper and trialkylsilyl propargyl bromide were examined. Perfluorohexyl copper reacted with 3-bromo-1-trimethylsilyl-1-propyne¹² to give 1:1 mixture of silylated perfluoroalkyne and perfluoroallene in 70% yield under the same conditions. These two regioisomers were difficult to separate, and the isomeric mixture was desilylated with the commercial Bu_4NF in THF or acetonitrile at 0 °C to give a perfluoroalkyne and perfluoroallene mixture (70% yield).



By use of the more sterically bulky tris(isopropyl)silylpropargyl bromide¹³ as the substrate, the perfluoroalkyne was obtained as expected with complete regioselectivity. The results suggest that the regioselectivity in the reactions of perfluoroalkyl copper with propargyl system in our cases depends on the bulkiness of the substituent at the γ -position of the propargyl compound¹⁴. By controlling the size of the substituent, either the perfluoroallene or perfluoroalkyne could be obtained selectively.



A typical experiment is described as follows: To a stirred suspension of copper powder (12.7 g, 0.2 mole) in dimethyl sulfoxide (100 ml) under argon atmosphere, perfluoro-n-octyl iodide (54.6 g, 0.1 mole) was added. The suspension was heated to 115 °C and was kept at 110 to 115 °C for one hour, during which time the solution turned to chocolate brown and then orange. The perfluoro-octyl copper reagent was cooled to 15 °C and the addition of propargyl bromide (11.9 g, 0.1 mole) was started while the pot temperature was maintained at 15 to 20 °C. Twenty minutes after the addition was complete, the product was removed by flash distillation from the reaction mixture; second distillation afforded the desired $\text{C}_6\text{F}_{13}\text{-CH=CH}_2$ product as a clear, colorless liquid, yield 34.0 g (74%). Bp. 86-90 °C/50 mm. $^1\text{H NMR}$ (CDCl_3): δ 5.30 (m, 1H), 5.18 (m, 2H); $^{19}\text{F NMR}$ (CDCl_3): -82.1 (tm, $J = 8.4$ Hz, 3F), -119.2 (s, br, 2F), -122.3 (br, 6F), -123.3 (s, br, 2F), -124.0 (s, br, 2F), -127.0 (s, br, 2F). Calc. for $\text{C}_{11}\text{H}_3\text{F}_{17}$: C: 28.84, H: 0.66, F: 70.50; Found: C: 28.53, H: 0.61, F: 70.30; [M]: Calc.: 457.9963; Found: 457.9972. IR (CDCl_3): 1987 cm^{-1} , 1950 cm^{-1} .

In a similar way, the rest of the compounds shown in the equations in the text were prepared and characterized.

[$\text{C}_6\text{F}_{13}\text{-CH=C=CH}_2$]: Bp. 88-90 °C/100 mm. $^1\text{H NMR}$ (CDCl_3): δ 5.20 (m, 2H), 5.36 (m, 1H); $^{19}\text{F NMR}$ (CDCl_3): -81.6 (t, $J = 9.8$, 1.8 Hz, 3F), -108.9 (m, 2F), -122.0 (m, 2F), -123.2 (m, 2F), -123.7 (m, 2F), -126.7 (m, 2F). Calc. for $\text{C}_9\text{H}_3\text{F}_{13}$: C: 30.19, H: 0.84, F: 68.97; Found: C: 29.86, H: 0.85, F: 68.68. [M] Calc: 358.0027; Found: 358.0028. IR (CDCl_3): 1988 cm^{-1} , 1954 cm^{-1} .

[$\text{C}_6\text{F}_{12}\text{-(CH=C=CH}_2)_2$]: Bp. 90 °C/12 mm. $^1\text{H NMR}$ (CDCl_3): δ 5.44 (m, 2H), 5.30 (dd, $J = 12.1$, 5.6 Hz, 4H); $^{19}\text{F NMR}$ (CDCl_3): -108.9 (quintet, $J = 4.9$ Hz, 4F), -122.1 (m, 4F), -124.0 (m, 4F). [M] Calc. for $\text{C}_{12}\text{H}_6\text{F}_{12}$: 378.0278; Found: 378.0282. IR (Neat): 1987 cm^{-1} , 1952 cm^{-1} .

[$\text{C}_8\text{F}_{16}\text{-(CH=C=CH}_2)_2$]: Bp. 105 °C/11 mm. $^1\text{H NMR}$ (CDCl_3): δ 5.43 (m, 2H), 5.30 dd, $J = 15$, 8 Hz, 4H); $^{19}\text{F NMR}$ (CDCl_3): -108.8 (s, 4F), -122.0 (s, 4F), -122.4 (s, 4F), -123.9 (s, 4F). [M] Calc. for $\text{C}_{14}\text{H}_6\text{F}_{16}$: 478.0214; Found: 478.0214. IR (Neat): 1987 cm^{-1} , 1952 cm^{-1} .

[$\text{C}_6\text{F}_{13}\text{-CH}_2\text{C}\equiv\text{C-Si(i-Pr)}_3$]: Bp. 99-100 °C/2.5 mm. $^1\text{H NMR}$ (CDCl_3): δ 3.04 (t, $J = 16$ Hz, 2H), 0.95 (s, br, 21H); $^{19}\text{F NMR}$ (CDCl_3): -81.4 (t, $J = 9.2$ Hz, 3F), -112.4 (m, 2F), -122.5 (m, br, 2F), -123.2 (m, br, 2F), -123.4 (m, br, 2F), -126.7 (m, 2F). Calc. for $\text{C}_{18}\text{H}_{23}\text{F}_{13}\text{Si}$: C: 42.02, H: 4.51, F: 48.00; Found: C: 42.68, H: 4.65, F: 47.70. IR (Neat): 2192 cm^{-1} , 1466 cm^{-1} .

[$\text{C}_6\text{F}_{13}\text{-CH}_2\text{C}\equiv\text{C-SiMe}_3$]: Bp. 55-56 °C/10 mm. $^1\text{H NMR}$ (CDCl_3): δ 3.09 (t, $J = 16$ Hz, 2H), 0.17 (s, 9H); $^{19}\text{F NMR}$ (CDCl_3): -81.4 (m, br, 3F), -112.4 (t, $J = 4$ Hz, 2F), -122.5 (br, 2F), -123.3 (br, 4F), -126.8 (m, 2F). Calc. for $\text{C}_{12}\text{H}_{11}\text{F}_{13}\text{Si}$: C: 33.50, H: 2.58, F: 57.40; Found: C: 32.90, H: 2.36, F: 57.67. [M-15]: Calc.: 415.0187; Found: 415.0087.

[C₆F₁₃-C(SiMe₃)=C=CH₂]: Bp. 58-60 °C/10 mm. ¹H NMR (CDCl₃): δ4.73 (t, J = 10 Hz, 2H), 0.10 (s, 9H); Calc. for C₁₂H₁₁F₁₃Si: C: 33.50, H: 2.58, F: 57.40; Found: C: 33.80, H: 2.16, F: 57.45.

[C₆F₁₃-CH₂C=CH]: Bp. 88-90 °C/100 mm. ¹H NMR (CDCl₃): δ3.02 (dt, J = 14, 2.5 Hz, 2H), 2.14 (t, J = 2.5 Hz, 1H); ¹⁹F NMR (CDCl₃): -81.4 (m, 3F), -108.8 (s, br, 2F), -122.3 (m, br, 2F), -123.4 (s, br, 2F), -123.9 (m, 2F), -126.7 (m, 2F). [M] Calc. for C₉H₃F₁₃: 358.0027; Found: 358.0106.

References and Notes:

- (1). Contribution No. 5441, US. Pat. Application Serial No. 442,676, November, 1989.
- (2). For example, see: J. A. Beel, H. C. Clark & D. Whyman, *J. Chem. Soc.*, C, **1969**, 4423; O. R. Pierce, E. T. McBee & G. F. Judd, *J. Am. Chem. Soc.*, **1954**, 76, 474; C. F. Smith, E. J. Soloski & C. Tamborski, *J. Fluorine. Chem.*, **1974**, 4, 35.
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- (7). G. A. Hartgraves & D. J. Burton, Third Chemical Congress of North America, Toronto, Canada, June, **1988**.
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- (10). R. Q. Brewster & T. Groening, "Org. Synth.", Collect Vol. II, 445-446, Note 1, **1943**; or Copper powder (99.995%) purchased from Aldrich Chemical Co. can be used directly.
- (11). The yields were lower if the product was allowed to stay longer in the reaction mixture. Presumably further reactions between R_fCu with F-allene product occurred.
- (12). L. Brandsma, Edited, "Preparative Acetylenic Chemistry", 2nd Edition, p.122, Elsevier, New York, **1988**.
- (13). See reference (12); also J. A. Marshall, T. M. Jenson & B. S. DeHoff, *J. Org. Chem.*, **1986**, 51, 4316.
- (14). If there are substituents on both α and γ-positions of the propargyl system, the sizes of α- and γ-substituents, the leaving group ability on the α-substituent and the size of R_fCu aggregate may also be important in the regioselectivity. We thank Professor D. J. Burton for providing us his complementary research results prior to publication.