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A convenient synthesis of fluoroalkyl ketones and sulfones from perfluoroisopropyl iodide

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Abstract

In the presence of hexaethylphosphorus triamide (HEPT), perfluoroisopropyl iodide is reacted directly with perfluoroalkyl acid halides, trifluoromethanesulfonyl fluoride, and methanesulfonyl chloride in benzonitrile to give the corresponding fluorinated ketones and sulfones. Diglyme is the solvent of choice for the reaction of pentafluorobenzoyl chloride with perfluoroisopropyl iodide in the presence of HEPT.

Keywords: Diglyme; Perfluoroisopropyl iodide; Benzonitrile

1. Introduction

During our study of the synthesis of highly fluorinated tertiary alcohols and ethers, we developed a need for various perfluorinated ketones. The most common route to perfluoroalkyl or aryl ketones is by using perfluorinated organometallic reagents [1–5]. These reactions must be carried out at low temperatures or significant decomposition of these reagents occurs [6]. Although addition of fluoroacyl fluorides to hexafluoropropene was used successfully to prepare fluoroketones which contain the perfluoroisopropyl group, the reactions require relatively high temperatures (100–125°C) and pressures and usually involve using stainless steel reaction vessels [7].

Recently, the use of (perfluoroalkyl)trialkylsilanes as perfluoroalkylating agents for various organic and inorganic substrates was reported [8–12]. While a number of fluorinated tertiary alcohols were successfully prepared by the fluoride ion-induced nucleophilic trifluoromethylation of carbonyl compounds, attempts to make perfluoroalkyl ketones usually resulted in the formation of tertiary alcohols or their ester derivatives [10,12].

Based on the earlier work of El Nigumi and Emeléus [13], Huang et al. [14] demonstrated that by using $R_fI\cdot P(N(CH_2CH_3)_2)_3$, aroyl chlorides are readily poly- or perfluoroalkylated even in the absence of poly- or perfluoroalkylsilanes. This method has not been used to prepare totally fluorinated aryl(alkyl) or dialkyl ketones nor poly- or perfluoroalkylsulfones.

We report here that in the presence of hexaethylphosphorus triamide (HEPT), perfluoroisopropyl iodide reacts directly with carbonyl fluoride, perfluoroalkyl acid halides, and pentafluorobenzoyl chloride to give the corresponding perfluorinated ketones. Moreover, this method can also be applied to the preparation of fluorinated sulfones from sulfonyl halides.

2. Results and discussion

Introduction of perfluoroalkyl moieties into other molecules is generally accomplished by using anionic perfluoroalkyl species. To this end, Ruppert's reagents [15], $R_fSi(CH_3)_3$, provide a convenient source of fluorinated carbanions by the following reaction, $R_fSi(CH_3)_3+F^- \rightarrow [R_f(CH_3)_3SiF]^-$. The fluorinated carbanion thus obtained reacts with various electrophiles, such as ketones, acid halides, arenesulfonyl fluorides, and other electrophilic sulfur and carbon centers to give the corresponding perfluoroalkylated products. On the other hand, it is of interest to note that the preparation of Ruppert's reagent [15] and other similar reagents also involves electrophilic trapping of anionic perfluoroalkyl species, viz

$$R_fI+P[N(CH_2CH_3]_2]_3$$

$$\rightarrow[(CH_3CH_2)_2N]_3PI^+R_f^- \xrightarrow{R_3E^+} R_fER_3$$

where E = Si, Sn, Ge, etc.

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Although no evidence was presented for the formation of such intermediates, nucleophilic attack of R_f^- on electrophiles seems plausible. We found that direct trapping of the postulated $[(CH_3CH_2)_2N]_3PI^+R_f^-$ intermediate by perfluoroalkyl acid halides results in the formation of perfluoroketones in moderate to good yields. Thus, when a perfluoroalkyl acid halide is condensed into a mixture of perfluoroisopropyl iodide with HEPT in benzonitrile at − 196°C and allowed to warm to 25°C, an exothermic reaction takes place immediately. Infrared spectra of the volatile materials from this reaction indicate the disappearance of the starting perfluoroalkyl acid halide and the formation of the perfluorinated ketone.

$$\underset{\mathbf{1}}{(CF_3)_2CFI} + \underset{\mathbf{2}}{R_fCOX} \xrightarrow[C_6H_5CN]{P[N(CH_2CH_3)_2]_3} \underset{\mathbf{3}}{R_fCOCF(CF_3)_2}$$

$X = F,Cl$

$R_f = CF_3$ **3a**
$R_f = C_2F_5$ **3b**
$R_f = C_3F_7$ **3c**

Unlike most cases involving organometallics synthetic schemes, no aqueous work-up is required, avoiding the formation of hydrated perfluoroalkyl ketones. The perfluorinated ketones from this reaction are easily separated from the solvents and by-products by trap-to-trap distillation.

Similarly, when carbonyl fluoride is reacted with two equivalents of $(CF_3)_2CFI$ under the same conditions, a symmetric perfluorinated ketone is formed.

$$2\underset{\mathbf{1}}{(CF_3)_2CFI} + \underset{\mathbf{4}}{COF_2} \xrightarrow[C_6H_5CN]{P[N(CH_2CH_3)_2]_3} \underset{\mathbf{5}}{(CF_3)_2CFCOCF(CF_3)_2}$$

Other solvents, such as acetonitrile and dichloromethane, can also be used without notable changes in the conversion. However, separation of products from these solvents is problematic because their boiling points are similar to the products' boiling points. Benzonitrile is therefore the solvent of choice due to its higher boiling point.

It is surprising that the reaction with pentafluorobenzoyl chloride to prepare pentafluorophenyl isopropyl ketone does not proceed in the presence of C_6H_5CN, CH_3CN, or CH_2Cl_2 as solvent. Fortunately, when diglyme is used, the reaction goes smoothly to give the expected pentafluorophenyl pentafluoroisopropyl ketone in fairly good yield.

$$\underset{\mathbf{1}}{(CF_3)_2CFI} + \underset{\mathbf{6}}{C_6F_5COCl} \xrightarrow[\text{diglyme}]{P[N(CH_2CH_3)_2]_3} \underset{\mathbf{7}}{C_6F_5COCF(CF_3)_2}$$

Unlike many highly fluorinated ketones, compound **7** is stable during aqueous work-up, and does not form a hydrate or a hemiketal, presumably due to steric hindrance.

Having established that perfluoroalkyl acid halides and pentafluorobenzoyl chloride can be used to trap the fluoroalkyl carbanion to obtain fluorinated ketones, we extended this reaction to synthesize fluorinated sulfones. Indeed, both trifluoromethanesulfonyl fluoride and methanesulfonyl chloride react satisfactorily with the $[(CH_3CH_2)_2N]_3PI^+ \, ^-CF(CF_3)_2$ salt to form the corresponding sulfones.

$$\underset{\mathbf{8}}{CF_3SO_2F} \xrightarrow[C_6H_5CN]{P[N(CH_2CH_3)_2]_3} \underset{\mathbf{10}}{CF_3SO_2CF(CF_3)_2}$$

$$\underset{\mathbf{1}}{(CF_3)_2CFI} +$$

$$\underset{\mathbf{9}}{CH_3SO_2Cl} \xrightarrow[C_6H_5CN]{P[N(CH_2CH_3)_2]_3} \underset{\mathbf{11}}{CH_3SO_2CF(CF_3)_2}$$

In conclusion, a simple, effective way of obtaining polyfluorinated ketones and sulfones has been developed by which perfluoroisopropyl iodide reacts directly with perfluoroalkyl or perfluoroaryl acid halides, and fluorinated or nonfluorinated sulfonyl halides in the presence of HEPT to obtain the corresponding perfluoroketones and polyfluorosulfones. Extension of this work to other perfluoroalkyl halides is currently under investigation.

3. Experimental

3.1. Materials

Hexaethylphosphorus triamide (HEPT) is prepared according to the literature [16]. Benzonitrile and acetonitrile are distilled from P_4O_{10} and stored over 4 Å molecular sieves. Diglyme is distilled from sodium before use. $(CF_3)_2CFI$, $CF_3C(O)Cl$, $CF_3CF_2C(O)Cl$, $CF_3CF_2CF_2C(O)Cl$, $C_6F_5C(O)Cl$, $C(O)F_2$, CF_3SO_2F (PCR), and CH_3SO_2Cl (Aldrich) are used as received.

3.2. General procedures

Volatile liquids are handled in a Pyrex vacuum system equipped with a Heise Bourdon tube gauge and a Televac thermocouple gauge. Conventional PVT techniques are used to quantitate volatile starting materials and products. All reactions are conducted in thick-walled, 100-ml round-bottomed flasks equipped with Teflon stopcocks. Products are separated by low temperature trap-to-trap distillation under dynamic vacuum. Infrared spectra are recorded on a Perkin-Elmer Model 1710 infrared Fourier transform spectrometer. ^{19}F and ^1H NMR spectra are obtained with a Bruker AC 200 Fourier transform NMR spectrometer using $CDCl_3$ as solvent and $Si(CH_4)_4$ and $CFCl_3$ as internal standard respectively. Mass spectra are recorded with a VG 7070HS mass spectrometer.

3.3. Reaction of perfluoroisopropyl iodide with perfluoropropanoyl chloride in the presence of HEPT, a typical procedure for the preparation of fluoroalkyl ketones and sulfones

Into a 100-ml, thick-walled flask equipped with a Kontes Teflon stopcock and a magnetic stirring bar are added 5-mmol

HEPT and 3-ml benzonitrile or acetonitrile. After being evacuated at −196°C, the flask is charged via vacuum transfer with 5-mmol perfluoroisopropyl iodide and 5-mmol pentafluoropropanoyl chloride. The mixture is allowed to warm to room temperature and stirred for one day. The products are then separated under dynamic vacuum and the desired perfluoroketone is found in a trap cooled at −50°C after passing through a trap at −20°C.

3.4. *Properties of $CF_3C(O)CF(CF_3)_2$ (**3a**) [7]*

This compound is obtained in 55% yield. Spectral data are as follows. IR (gas): 1796 s (v_{CO}), 1378 m, 1300 vs, 1259 vs, 1200.5 vs, 117, s, 1122 vs, 1054 s, 987 s, 874 s, 726 s cm^{-1}. ^{19}F NMR: δ −74.1 (6F, CFCF_3); −75.8 (3F, $COCF_3$); −192.3 (1F, *CF*CF_3) ppm; MS (CI^+) [*m/e* (species) intensity]: 267 ($M^+ + 1$) 11.7; 247 (M^+–F) 2.3; 197 (M^+–CF_3) 21.8; 169 ($C_3F_7^+$) 10.6; 97 (M^+–C_3F_7) 71.5; 69 (CF_3^+) 100.

3.5. *Properties of $CF_3CF_2C(O)CF(CF_3)_2$ (**3b**) [17]*

This compound is obtained in 58% yield. Spectral data are as follows. IR (gas): 1784 s (v_{CO}), 1326 m, 1302 vs, 1248.5 vs, 1192 vs, 1173.5 vs, 1136 vs, 1025 s, 986 s, 720 s cm^{-1}. ^{19}F NMR: δ −73.7 (6F, CFCF_3); −81.6 (3F, $CF_2$$CF_3$); −120.8 (2F, $CF_2$$CF_3$); −191.4 (1F, *CF*$CF_3$) ppm; MS ($CI^+$) [*m/e*(species) intensity]: 317 ($M^+ + 1$) 0.9; 197 (M^+–C_2F_5) 64.6; 169 ($C_3F_7^+$) 29.7; 147 (M^+–C_3F_7) 69.1; 119 ($C_2F_5^+$) 85.2; 100 ($C_2F_4^+$) 18.0; 69 (CF_3^+) 100.

3.6. *Properties of $CF_3CF_2CF_2C(O)CF(CF_3)_2$ (**3c**) [7]*

This compound is obtained in 60% yield. Spectral data are as follows. IR (gas): 1783 s (v_{co}), 1353 m, 1268 vs, 1192 vs, 1173 vs, 1140 vs, 1122 s, 1107 s, 990 s, 959 s, 904 s cm^{-1}; ^{19}F NMR: δ −74.0 (6F, CFCF_3); −80.9 (3F, $CF_2$$CF_3$); −118.0 (2F, $COCF_2$); −125.7 (2F, $CF_2$$CF_3$); −190.9 (1F, *CF*$CF_3$) ppm; MS ($CI^+$) [*m/e* (species) intensity]: 367 ($M^+ + 1$) 17.4; 347 (M^+–F) 13.5; 197 (M^+–C_3F_7) 92.3;169 ($C_3F_7^+$) 100; 119 ($C_2F_5^+$) 9.2; 100 ($C_2F_5^+$) 11.8; 69 (CF_3^+) 91.5.

3.7. *Properties of $(CF_3)_2$ CF $C(O)CF(CF_3)_2$ (**5**) [7]*

This compound is obtained in 61% yield. Spectral data are as follows. IR (gas): 1775 m (v_{co}), 1268 vs, 1181 vs, 1153 vs, 1122 vs, 1043 s, 1010 vs, 959 s, 904 s, 754 s, 728 s cm^{-1}: ^{19}F NMR: δ −73.6 (12F, CFCF_3); −184.6 (2F, *CF*CF_3) ppm; MS (CI^+) [*m/e* (species) intensity]: 367 ($M^+ + 1$) 1.7; 197 (M^+–C_3F_7) 43.9; 169 ($C_3F_7^+$) 15.4; 69 (CF_3^+) 100.

3.8. *Properties of $C_6F_5C(O)CF(CF_3)_2$ (**7**) [18]*

This compound is obtained in 69% yield, bp 48°C/0.05 Torr. Spectral data are as follows. IR (gas): 1751 m (v_{co}), 1655 m, 1489 m, 1299 s, 124, s, 1158 m, 1091 s, 1009 m cm^{-1}; ^{19}F NMR: δ −75.3 (6F, CFCF_3); −138.6 (2F, m, *o*-F); −145.0 (1F, m, *p*-F); −158.6 (2F, m, *m*-F); −178.7 (1F, *CF*CF_3) ppm; MS (CI^+) [*m/e* (species) intensity]: 365 ($M^+ + 1$) 42.6; 364 (M^+) 10.7; 346 (M^+–F+1) 8.0; 345 (M^+–F) 72.4; 276 (M^+–CF_3–F) 9.4; 198 ($C_3F_7CO^+ + 1$) 8.8; 197 (M^+–C_6F_5) 4.7; 196 ($C_6F_5CO^+ + 1$) 7.0; 195 ($C_6F_5CO^+$) 100; 169 ($C_3F_7^+$) 100; 167 ($C_6F_5^+$) 15.1; 69 (CF_3^+) 36.9.

3.9. *Properties of $CF_3SO_2CF(CF_3)_2$ (**10**)*

This compound is obtained in 90% yield. Spectral data are as follows. IR (gas): 1480 vs (υ_{SO_2}), 1265 vs, 1196 vs, 1144 vs, 1115 vs, 1054 s, 977 s, 949 s, 736 s cm^{-1}; ^{19}F NMR: δ −70.1 (3F, CF_3); −70.8 (6F, CFCF_3); −171.3 (1F, *CF*CF_3) ppm; MS (CI^+) [*m/e* (species) intensity]: 303 ($M^+ + 1$) 1.0; 233 (M^+–CF_3) 1.2; 69 (CF_3^+) 100.

3.10. *Properties of $CH_3SO_2CF(CF_3)_2$ (**11**) [19]*

This compound is obtained in 66% yield. Spectral data are as follows. IR (gas): 2883 s, 1456 m (υ_{SO_2}), 1373 m, 1280 s, 1224 s, 1105 s, 975 m, cm^{-1}; ^{19}F NMR: δ −71.1 (6F, CFCF_3); −181.6 (1F, *CF*CF_3) ppm; ^1H NMR: 3.61 (SO_2CH_3) ppm; MS (CI^+) [*m/e* (species) intensity]: 233 (M^+–CH_3) 100; 169 ($C_3F_7^+$) 4.9; 150 ($C_3F_6^+$) 6.6; 79 ($CH_3SO_2^+$) 5.2; 69 (CF_3^+) 35.8.

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References

[1] R.D. Chambers, D.J. Spring, J. Chem. Soc. C (1968) 2394.
[2] L.S. Chen, L. Tamborski, J. Fluorine Chem. 19 (1981–1982) 43.
[3] P. Moreau, N. Reawane, A. Commeyras, Bull. Soc. Chim. Fr-Part 2 (314) (1984) 117.
[4] H. Uno, Y. Shiraishi, K. Simikawa, H. Suzuki, Chem. Lett. (1987) 1153.
[5] L.S. Chen, G.J. Chen, M.T. Ryan, C. Tamborski, J. Fluor. Chem. 34 (1987) 299.
[6] R.N. Haszeldine, J. Chem. Soc. (1954) 1273.
[7] R.D. Smith, F.S. Fawcett, D.D. Coffman, J. Am. Chem. Soc. 84 (1962) 4285.
[8] G.K.S. Prakash, R. Krishnamurti, G.A. Olah, J. Am. Chem. Soc. 111 (1989) 393.
[9] A.A. Kolomeitsev, V.N. Movchun, N.V. Kondratenko, Y.L. Yagupolski, Synthesis (1990) 1151.
[10] R. Krishnamurti, D.R. Bellew, G.K.S. Prakash, J. Org. Chem. 56 (1991) 984.
[11] S.P. Kotun, J.D.O. Anderson, D.D. DesMarteau, J. Org. Chem. 57 (1992) 1124.

[12] N.R. Patel, R.L. Kirchmeier, Inorg. Chem. 31 (1992) 2537.

[13] Y.O. El Nigumi, H.J. Emeléus, Inorg. Nucl. Chem. 32 (1970) 321.

[14] W.-Y. Huang, C.-M. Hu, Y.-B. He, H.-F. Zhou, J. Fluor. Chem. 48 (1990) 145.

[15] I. Ruppert, K. Schich, W. Volbach, Tetrahedron Lett. 25 (1984) 2195.

[16] C. Stuebe, H.P. Lankelma, J. Am. Chem. Soc. 78 (1956) 976.

[17] Ya.M. Vilenchik, V.A. Soshin, L.M. Novoselitskaya, G.I. Lekontseva, P.G. Neifel'd, Zh. Vses. Khim. O-va. 23 (1978) 236.

[18] R.D. Chambers, C.A. Heaton, W.K.R. Musgrave, J. Chem. Soc. C (1968) 1933.

[19] R.N. Haszeldine, R.B. Rigby, A.E. Tipping, J. Chem. Soc., Perkin Trans. I (1973) 676.