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The First Example of Sulfinatodehalogenation of 2,2,2-Trifluoroethyl Halides: A Novel Method for Trifluoroethylation of Alkenes and Alkynes

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Abstract: 2,2,2-Trifluoroethylation of alkenes and alkynes with 2,2,2-trifluoroethyl iodide or bromide and sodium dithionite in DMSO or CH_3CN/H_2O can occur under mild conditions.

Keywords: 2,2,2-Trifluoroethyl Halides; Trifluoroethylation; Alkenes; Alkynes

Sulfinatodehalogenation of perhalocarbons, discovered and developed by Huang and his students since 1983, is becoming an important reaction in organofluorine chemistry.[1] Using cheap sulfur-containing reductants (e.g. $Na_2S_2O_4$) under mild conditions, per- and polyfluoroalkyl halides (R_FX, X=Br, I; R_FCCl_3) can give smoothly the corresponding sulfinate salts. More importantly, this method has been widely applied to perfluoroalkylate alkenes, dienes, allenes, alkynes and aromatics. However, this system is confined to perhalocarbons.[2] Only recently, was it found that the difluoromethylation of alkenes and alkynes with difluoroiodomethane could occur under the standard sulfinatodehalogenation conditions.[3]

On the other hand, it is well known that 2,2,2-trifluoroethyl halides can not be used as trifluoroethylation agents by nucleophilic substitution because the trifluoromethyl group strongly deactivates the neighbouring carbon.[4] Accordingly, alternative approaches such as the use of iodonium salts (e.g. 2,2,2-trifluoroethyl phenyl iodonium triflate, FMITS)[5] and anodic oxidation of 2,2,2-trifluoroethyl sulfides[4] have been developed for introducing trifluoroethyl groups into organic molecules. Additionally, a free radical addition of 2,2,2-trifluoroethyl iodide to electron-rich terminal alkenes has been reported.[6] The drawback of this method is that the yields were not high; the initiator, dibenzoyl peroxide or 2,2-azobisisobutyronitrile must be added in successive portions, and pure adducts have not been obtained due to the difficulty of removing the by-product resulting from the initiator decomposition. Therefore, the iodide adducts obtained had to be reduced to the corresponding trifluoroalkanes.

In connection with these results, we were interested in using 2,2,2-trifluoroethyl halides [CF_3CH_2X, **1**, X=I(a), Br(b), Cl(c)] as substrates to examine the possibility of sulfinatodehalogenation and, if feasible, develop a new convenient method for trifluoroethylation of alkenes and alkynes. This communication presents our results.

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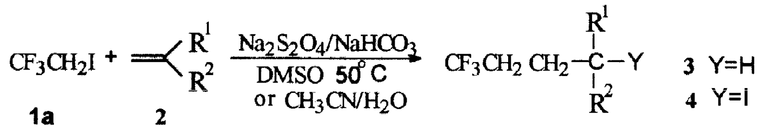
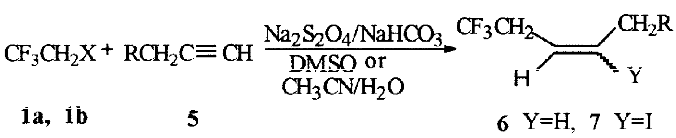
We found that the sulfinatodehalogenation system can be successfully applied to trifluoroethylation of alkenes and alkynes. Thus, treatment of **1a** with either electron-rich or electron-deficient alkenes **2**, $Na_2S_2O_4$ and $NaHCO_3$ in DMSO at 50°C for 4 h gave the iodine-free adducts, **3**. The yields of products with electron-rich olefins were much better than those with electron-deficient ones. However, when using CH_3CN/H_2O instead of DMSO as solvent, the normal adducts **4** as well as reduction products **3** were obtained (**4** : **3** = 2-3 : 1) and were easily separated.

Like **1a**, **1b** was also able to undergo the addition reaction with alkenes at a slightly higher temperature but gave only products **3** with lower yields in either DMSO or CH_3CN/H_2O. However, **1c** did not undergo the similar reaction under similar conditions.

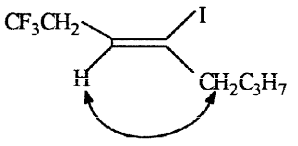


R^2= H: R^1= $-C_4H_9$(**2a**), $-C_6H_{13}$(**2b**), $-CH_2OAc$(**2c**), $-CH_2OCH_2CH{=}CH_2$(**2d**), $-CH_2CH_2CH{=}CH_2$(**2e**), $-CO_2C_2H_5$(**2f**),
R^2= CH_3: R^1 = $-CO_2CH_3$(**2g**),

This sulfinatodehalogenation method may be successfully extended to alkynes,[7] unlike the free radical initiation addition of **1a** to alkynes.[8] It was interesting that, for **1a** in DMSO or in CH_3CN/H_2O, the corresponding vinyl iodides 7 were obtained, whereas for **1b** the reduction products **6**. The products **6** and **7**, except 7c, were mixtures of E- and Z- isomers. The stereochemistry of 7 was assigned by its NOESY correlation between the Z-vinyl proton and $-CH_2R$. The ultimate product of **7c** may result from the intramolecular hydrogen-fluorine bonding which enhances the configurational stability of the corresponding cis-vinyl radical. All the trifluoroethylation results are listed in Table 1.



R= $-C_3H_7$(**5a**), $-C_5H_{11}$(**5b**), $-OH$(**5c**), $-OCH_3$(**5d**)



NOESY of **7a** (Z-)

In the absence of alkenes or alkynes, simple treatment of 2,2,2-trifluoroethyl iodide or bromide with $Na_2S_2O_4$ in CH_3CN/H_2O (v/v=1:1) gave the corresponding sodium sulfinate **8** in 80% and 38% yields, respectively. Chlorination of **8** with chlorine gas according to a known procedure,[1] afforded 2,2,2-trifluoroethanesulfonyl chloride **9** in 58% isolated yield in addition to a small amount of tresylic acid, **10** (18% isolated yield). Compared with the known methods for synthesizing **9** and/or **10**, e.g. from the oxidation of 2,2,2-trifluoroethyl sulfides by several steps,[9] this method seems more straightforward and much more convenient.

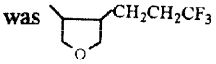
$$CF_3CH_2X + Na_2S_2O_4 \xrightarrow[40\text{-}65^\circ C,\ 10h]{CH_3CN/H_2O} CF_3CH_2SO_2Na \xrightarrow[H_2O,\ -5^\circ C]{Cl_2} CF_3CH_2SO_2Cl + CF_3CH_2SO_3H$$

1a, **1b** **8** **9** **10**

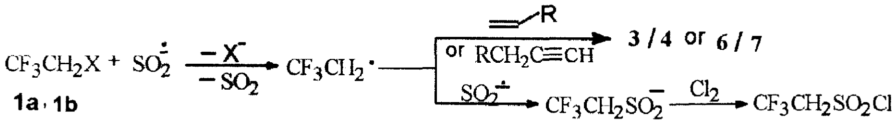
Table 1 : **1a** and **1b** reacted with alkenes and alkynes (**1**:$Na_2S_2O_4$=1:2)

Entry	1	2 or 5	Solvent	T(°C)	Time(h)	Product(E/Z)[a]	Yield%(Conv.%)[b]
1	**1a**	**2a**	DMSO	50	4	**3**	73 (100)
2	**1b**	-	-	60	10	**3**	50 (70)
3	**1a**	**2b**	-	50	4	**3**	81 (100)
4	-	-	CH_3CN/H_2O	60	6	**4**/**3**=2.8	52 (100)
5	**1b**	-	-	65	10	**3**	47 (75)
6	-	-	DMSO	60	10	**3**	55 (75)
7	**1a**	**2c**	-	50	4	**3**	74 (100)
8	-	-	CH_3CN/H_2O	60	6	**4**/**3**=2.9	49 (100)
9	**1b**	-	DMSO	60	10	**3**	48 (75)
10	**1a**	**2d**	-	50	4	**3**	60[c] (100)
11	**1b**	-	-	65	10	**3**	60[c] (70)
12	**1a**	**2e**	-	50	4	**3**	57 (100)
13	-	**2f**	-	55	10	**3**	30 (100)
14	-	**2g**	-	55	10	**3**	35 (100)
15	-	**5a**	-	55	6	**7**(29/71)	75 (100)
16	-	-	CH_3CN/H_2O	50	6	**7**(25/75)	68 (100)
17	**1b**	-	DMSO	60	10	**6**(30/70)	45 (70)
18	**1a**	**5b**	-	55	6	**7**(27/73)	66 (100)
19	-	-	CH_3CN/H_2O	50	6	**7**(25/75)	61 (100)
20	**1b**	-	-	65	10	**6**(28/72)	45 (80)
21	-	-	DMSO	65	10	**6**(29/71)	53 (77)
22	**1a**	**5c**	-	60	6	**7**(100/0)	64 (100)
23	-	**5d**	-	55	6	**7**(25/75)	71 (100)

a. The E/Z isomers were determined by ^{1}H NMR and NOESY and all the products, except known **3a**, **3b**, **3e**, were characterized by IR, ^{19}F, ^{1}H NMR, MS and elemental analyses. b. determined by ^{19}F NMR. c. The product of **2d** with **1a** or **1b** was



The sulfinatodehalogenation of 1,1,1-trifluoroethyl halides, like that of perfluoroalkyl halides (R_FX), can be rationalized in terms of single electron-transfer from $SO_2^{\dot{-}}$ generated by the decomposition of $Na_2S_2O_4$ to the known electron acceptor **1a**[10] or **1b**, giving the sodium trifluoroethanesulfinate. This intermediate either adds to alkenes or alkynes to afford the adducts or reacts with chlorine gas producing the corresponding sulfonyl chloride. It is worth mentioning that the sulfinatodehalogenation-induced perfluoroalkylation of alkenes and alkynes is usually carried out in a mixture of organic solvent / H_2O (e.g. with $Na_2S_2O_4$, CH_3CN/ H_2O = 1:1) yielding only halide adducts. However, in the present case, for **1a** with alkenes in CH_3CN/H_2O, both halide and hydride adducts were obtained, whereas in DMSO, the hydrides became the sole products. For **1a** with alkynes, either in DMSO or in CH_3CN/H_2O, the vinyl iodides were the only products. The product variations with the solvent may be ascribed to the first formed intermediate radical, $CF_3CH_2\overset{|}{\underset{|}{C}}\text{-}\overset{|}{\underset{|}{C}}^{\bullet}$, undergoing competitive abstractions of either halogen or hydrogen atoms from **1** and solvent, respectively. Indeed, it was found very recently that, even in a mixture of organic solvent / water in a constant v/v , when changing the organic solvent from CH_3CN, CH_2Cl_2 to DMF, the amounts of hydride product increased and finally became the exclusive product in the reaction of CF_3CCl_3 with 4,4-disubstituted hepta-1,6-diene.[11] The reduction of the iodide products by an excesses of $Na_2S_2O_4$, or the reduction of the intermediate radical by another $SO_2^{\dot{-}}$ to form an anion followed by protonation may be less important because the final halide adducts are inert in the presence of $Na_2S_2O_4$ under the reaction conditions.



In conclusion, this is the first example of sulfinatodehalogenation of 2,2,2-trifluoroethyl halides and provides a convenient method for trifluoroethylating alkenes and alkynes.

Acknowledgment. We thank Professor W.-Y. Huang for his encouragement and the Natural Science Foundation of China for support of this work.

References and Notes:

1. Reviews: a. Huang, W.-Y. *J. Fluorine Chem.* **1992**, 58; b. Huang, W.-Y.; Lu, L. "*Sulfinatodehalogenation*" in "*Organofluorine Chemistry in China*" Chapter 8, ed. by Huang, W. Y. p. 203, Shanghai Science and Technology Press, **1996**.

2. Huang, W.-Y.; Huang, B.-N.; Chen, J.-L. *Acta. Chimica Sinica* **1986**, *44*, 45.

3. Cao, P.; Duan, J.-X.; Chen, Q.-Y. *J. Chem. Soc., Chem. Commun.* **1994**, 737.

4. Fuchigami, T.; Yamamoto, K.; Nakagaw, Y. *J. Org. Chem.* **1991**, *56*, 137. and references cited therein.

5. Montanari, V.; Resnati, G. *Tetrahedron Lett.* **1994**, *35*, 8015. and references cited therein.

6. Cloux, R.; Kovats, E. *Synthesis* **1992**, 409.

7. Typical Procedure for trifluoroethylation: Under an N_2 atmosphere, **1a** (1.05g, 5 mmol) was added to a mixture of $Na_2S_2O_4$ (1.74g, 10 mmol), $NaHCO_3$ (0.84g, 10 mmol) and **5a** (0.5g, 6 mmol) in DMSO(10mL). The solution was stirred for 6 h at 55°C. The mixture was cooled and H_2O(10 mL) was added, then the organic phase was extracted with ether, and dried over anhydrous $MgSO_4$. After evaporation of ether and chromatography on silica gel, **7a** was obtained (1.1g, yield 75%, E/Z=29/71). E-isomer: ^{19}F NMR δ(300 MHz, $CDCl_3$, CF_3CO_2H as reference): -11.2(t, $J_{H,F}$ = 12Hz, CF_3), ^1H NMR δ(300 MHz, $CDCl_3$): 6.18(t, J=7.5Hz, 1H, =CH), 2.72-2.82(m, 2H, CF_3CH_2), 2.39(t, J=7.5Hz, 2H, $=CICH_2$), 1.24-1.40(m, 4H, $-CH_2CH_2-$), 0.90(t, J=7.2Hz, 3H, CH_3); Z-isomer: ^{19}F NMR δ($CDCl_3$): -10.7(t, $J_{H,F}$ = 12Hz, CF_3). ^1H NMR δ($CDCl_3$): 5.59(tt, J=6.5Hz, 1.2Hz,1H, =CH), 2.88-3.03(m, 2H, CF_3CH_2), 2.52(t, J=6.5Hz, 2H, $=CICH_2$), 1.49-1.58(m, 4H, $-CH_2CH_2-$), 0.90(t, J=7.2Hz, CH_3); Ms: 292(M^+, 100), 250($M^1-C_3H_6$, 60.74), 165(M^+-I, 52.54), 123$M^+-I-C_3H_6$, 72.09), 69(CF_3^+, 10.04). HRMS for $C_8H_{12}F_3I$: Calcd: 291.9936, Found: 291.9942.

8. Sun, W.-C.; Prestwich, G. D. *Tetrahedron Lett.* **1990**, *31*, 801.

9. Bunyagidj, C.; Piotrowska, H.; Aldridge, M. H. *J. Org. Chem.* **1981**, *46*, 3335.

10. **1a** has been used as an electron acceptor reacting with 9-substituted fluorenide carbanions, but no products containing CF_3CH_2 moiety were observed: Bordwell, F. G.; Wilson, C. A. *J. Am. Chem. Soc.* **1987**, *109*, 5470.

11. Zhao, G.; Yang, J.; Huang, W.-Y. *J. Fluorine Chem.* **1997**, *86*, 89.