CHEMISTRY LETTERS, pp. 2183-2186, 1991.

Regioselective Monofluorination of Hydrofluorocarbons by the Use of Cobalt Trifluoride

Akira SEKIYA,* Shigeru KUROSAWA, and Toshiro YAMADA†
National Chemical Laboratory for Industry,
1-1 Higashi, Tsukuba, Ibaraki 305
†Nippon Zeon Co., LTD., Research and Development Center,
1-2-1 Yako, Kawasaki-ku, Kawasaki, Kanagawa 210

The geminal-difluoro hydrofluorocarbons (HFCs) were fluorinated by the use of cobalt trifluoride (CoF_3). Regioselective monofluorination of geminal-difluoro compound was achieved on methylene position neighboring gem-difluoromethylene group, and trifluoro compounds were obtained in good yields under mild conditions.

The legislated chlorofluorocarbons (CFCs) are used for a wide range of applications such as refrigerants, aerosol propellants, blowing agents and cleaning agents. But in the stratosphere these CFCs can cause the depletion of the stratospheric ozone layer. It is the most important subject to develop CFCs alternatives which can cause no pollution. One of the candidates is hydrofluorocarbons (HFCs).1a) Because HFCs have no chlorine atom which initiates free radical chain reactions to cause the depletion of ozone layer, and their physical or chemical properties are close to those of CFCs.1b)

Cobalt trifluoride (CoF_3) has been used as an important fluorinating agent, particularly for complete fluorination of hydrocarbons by the Fowler process.2) But these reactions are carried out at high temperatures, and regioselective fluorination, which is useful for preparing HFCs, is not achieved because of little difference between bond energies of C-H bonds in hydrocarbons.3) The well-studied compounds in the reaction are ethane,4a) ethene,4b) 2-methylpropane,5a) and butane:5b) the distribution of hydrogens in the partially fluorinated products is almost random in the former two cases, and in the latter two is given a mixture consisting of at least 30 or 51 components. Extensive skeletal rearrangement occurs during the fluorination of saturated aliphatics: for example, octane over CoF_3 gives about 50% of perfluorinated branched-chain C_8-isomers or C_8-cyclic compounds, along with 50% of straight-chain perfluorooctane.[5c)] The fluorination of aliphatic compounds over CoF_3 is not available in synthetic manners. In this paper, we describe regioselective monofluorination of gem-difluoro hydrocarbons by CoF_3 for the first time.

Addition of hydrogen fluoride to acethylenes (Scheme 1) was done according to the literature method.[6)] The gem-difluoro HFCs **1** was prepared from hydrogen fluoride (125 mmol) and acetylene (50 mmol). The addition products were identified by gas chromatography (GC), ^{19}F-NMR,[7)] and ^{1}H-NMR. Yields were determined by GC (TCD detector) and ^{19}F-NMR ($C_6H_5CF_3$ was used as the internal standard). The products were distilled in vacuo, and adducts **1** were obtained in 85 - 40% yields (purity 99%).

$$\underset{(R = H,\ CH_3,\ CH_2CH_3,\ Cl)}{CH{\equiv}C\text{-}CH_2R} \xrightarrow{HF} \underset{\mathbf{1}}{CH_3CF_2CH_2R} \xrightarrow{CoF_3} \underset{\mathbf{2}}{CH_3CF_2CFHR} \qquad (\mathrm{I})$$

A general procedure for the fluorination of **1** (Scheme 1) is as follows; Cobalt trifluoride (200 mmol) was placed into a reactor. Compound **1** (3 or 20 mmol) was introduced into the reactor at -196 ℃ in the same manner as described before.[8)] The reactor was allowed to warm up slowly to ambient temperature (20 ℃) over 1.5 h, and then heated under the specified conditions. It was cooled to -196 ℃, and volatile products were removed under reduced pressure. Hydrogen fluoride was removed from the mixture by using sodium fluoride. The products were identified by ^{19}F-NMR,[7)] ^{1}H-NMR, IR, and GC-MS. The yield of products **2** and the recovery of **1** were determined by GC and ^{19}F-NMR (int. $C_6H_5CF_3$). Cobalt trifluoride which was partially reduced to CoF_2 by the fluorination reaction was regenerated by the oxidation with fluorine at 200 ℃ before next fluorination.

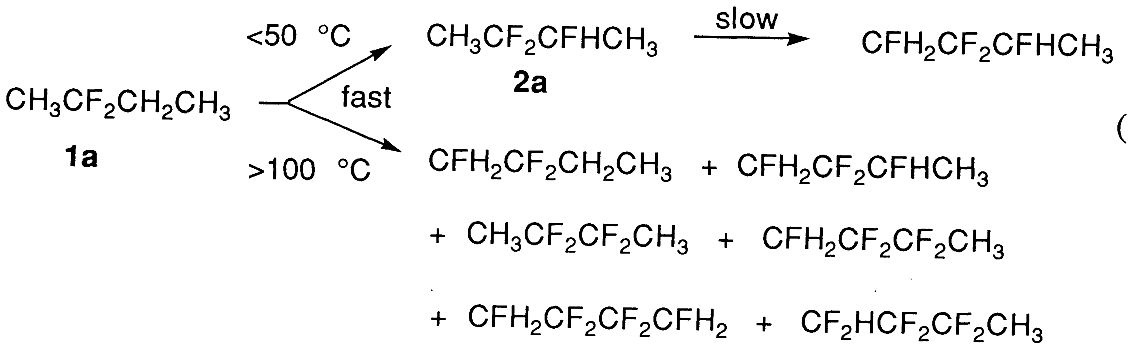
When 2,2-difluorobutane (**1a**) was fluorinated at 25 ℃ for 1 h, monofluorinated compound, 2,2,3-trifluorobutane (**2a**), was obtained in excellent yield as the major product (Table 1). Prolonged reaction time increased the yield of **2a**. When the reaction temperature was raised, the yield of **2a** was decreased and polyfluorinated by-products such as 1,2,2,3-tetrafluorobutane, 2,2,3,3-tetrafluorobutane, and 1,2,2,3,3-pentafluorobutane were resulted. The major product was no longer **2a** at 100 ℃. Thus, the successful monofluorination was found to require the low reaction temperatures (Scheme 2).

2,2-Difluoropropane (**1b**) and 2,2-difluoropentane (**1c**) were monofluorinated regioselectively to give as the major product 1,2,2-trifluoropropane (**2b**) and 2,2,3-trifluoropentane (**2c**), respectively, in excellent yields.

Table 1. The fluorination of gem-difluoro HFCs by the use of CoF_3

Substrate	Reaction conditions		Recov.[a]	Monofluorinated product		
(3 mmol)	Temp / °C	Time / h	%	Main product	No.	Yield[b] / %
$CH_3CF_2CH_2CH_3$	25	1	3	$CH_3CF_2CFHCH_3$	**2a**	78
$CH_3CF_2CH_2CH_3$	25	2	1	$CH_3CF_2CFHCH_3$	**2a**	82
$CH_3CF_2CH_2CH_3$	50	1	1	$CH_3CF_2CFHCH_3$	**2a**	76
$CH_3CF_2CH_2CH_3$	100	1	2	$CH_3CF_2CFHCH_3$	**2a**	26
$CH_3CF_2CH_2CH_3$	150	1	1	$CH_3CF_2CFHCH_3$	**2a**	21
$CH_3CF_2CH_2CH_3$	200	1	0	$CH_3CF_2CFHCH_3$	**2a**	12
$CH_3CF_2CH_2CH_3$[c]	40	1.5	1	$CH_3CF_2CFHCH_3$	**2a**	85
$CH_3CF_2CH_3$	25	2	57	$CH_3CF_2CFH_2$	**2b**	24
$CH_3CF_2CH_3$	25	14	1	$CH_3CF_2CFH_2$	**2b**	73
$CH_3CF_2CH_3$[c]	25	96	0	$CH_3CF_2CFH_2$	**2b**	85
$CH_3CF_2CH_3$	50	8	1	$CH_3CF_2CFH_2$	**2b**	71
$CH_3CF_2CH_3$	100	1	2	$CH_3CF_2CFH_2$	**2b**	65
$CH_3CF_2CH_2CH_2CH_3$	25	2	1	$CH_3CF_2CFHCH_2CH_3$	**2c**	67
$CH_3CF_2CH_2CH_2CH_3$	25	11	0	$CH_3CF_2CFHCH_2CH_3$	**2c**	69
$CH_3CF_2CH_2Cl$	25	2	89	CH_3CF_2CFHCl	**2d**	5
$CH_3CF_2CH_2Cl$	25	134	15	CH_3CF_2CFHCl	**2d**	50
$CH_3CF_2CH_2Cl$	50	72	12	CH_3CF_2CFHCl	**2d**	43
$CH_3CF_2CH_2Cl$	100	8	2	CH_3CF_2CFHCl	**2d**	48

a)Reactant recovery was determined by GC (TCD detector). b)Yields were determined by ^{19}F-NMR (int. $C_6H_5CF_3$). c)Substrate 20 mmol was employed.



(II)

1-Chloro-2,2-difluoropropane (**1d**) was also monofluorinated to afford 1-chloro-1,2,2-trifluoropropane (**2d**) in good yield.

The substituent R may affect the fluorination rate. Under the same reaction condition (25 °C, 2 h), the rate of monofluorination of **1** was decreased in the order, CH_3, C_2H_5, H, and Cl.

The selectivity of fluorination of HFCs would be explained from the stability of intermediate cations. The fluorination by CoF_3 is considered to proceed via carbocation.[9a)] In this case, there are three possible carbocations.[9b)] One is a cation at the methyl group neighboring of CF_2: **A**, the second case is a cation at methylene group adjacent to CF_2: **B**, and the third is a cation at methyl or ethyl group etc.: **C**. The cation at **B** is the most stabilized by resonance effect due to CF_2, and by electron-donating due to the adjacent alkyl group (R). These effects are remarkable, so that the fluorination at the **B** position would occur preferentially, in particular at low temperatures. At high temperatures the fluorination would come to progress in a random manner.

References

1) a) " Chlorofluorocarbons: Global Environmental Impact and Countermeasures," in " Kikan Kagaku Sosetsu," ed by the Chemical Society of Japan, Tokyo (1991); b) A. Sekiya, *IEA Heat Pump Center Newsletter*, **9**, 7 (1991).
2) R. E. Banks and J. C. Tatlow, *J. Fluorine Chem.*, **33**, 227 (1986).
3) M. Stacey and J. C. Tatlow, *Adv. Fluorine Chem.*, **1**, 166 (1960).
4) a) D. A. Rausch, R. A. Davis, and D. W. Osborne, *J. Am. Chem. Soc.*, **28**, 494 (1963); b) J. Burdon, J. R. Knights, I. W. Parsons, and J. C. Tatlow, *Tetrahedron*, **32**, 1041 (1976).
5) a) J. Burdon, T. N. Huckerby, and R. Stephens, *J. Fluorine Chem.*, **10**, 523 (1977); b) J. Burdon, S. T. Ezmirly, and T. N. Huckerby, *ibid.*, **40**, 283 (1988); c) J. Burdon, *ibid.*, **35**, 15 (1987).
6) A. L. Henne and E. P. Plueddeman, *J. Am. Chem. Soc.*, **65**, 587 (1943).
7) " Compilation of Reported ^{19}F NMR Chemical Shifts, 1951-1967," ed by C. H. Dungan and J. R. V. Wazer, Wiley-Interscience, New York (1970).
8) A. Sekiya and K. Ueda, *Chem. Lett.*, **1991**, 1421.
9) a) J. Burdon, I. W. Parsons, and J. C. Tatlow, *Tetrahedron*, **28**, 43 (1972); b) Possible carbocation centers are considered as follows;
A **B** **C**
$CH_3CF_2CH_2R$.

(Received September 2, 1991)