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REACTION OF (POLYFLUOROALKYL)TRIMETHYLAMMONIUM SALTS WITH HYDROXIDE ION

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SUMMARY

(Polyfluoroalkyl)trimethylammonium iodides (**1a–d**), $R_fCF_2CH_2N^+Me_3I^-$ (R_f; **a** = HCF_2, **b** = CF_3, **c** = $H(CF_2)_3$, **d** = $H(CF_2)_5$), reacted easily with an equimolar amount of sodium hydroxide in water at 20 °C to give *Z* isomers of (polyfluoro-1-alkenyl)trimethylammonium iodides (**2a–d**), $R_fCF{=}CHN^+Me_3I^-$, quantitatively. However, treatment of **1** with 3 equimolar amounts of sodium hydroxide yielded different products depending on the length of the R_f chain: **1a** gave (2-oxo-3,3-difluoropropyl)trimethylammonium iodide (**3a**), which had a great tendency to form the hydrate **4a**; **1b** produced a mixture of the analogous ketone **3b** and betaine **6**; **1c** and **1d** afforded the corresponding 1*H*,ω*H*-perfluoroalkanes **7c** and **7d**, respectively, together with **6**.

INTRODUCTION

The quaternary ammonium salts are well known to undergo several characteristic reactions, such as Hofmann degradation by pyrolysis [1], Stevens rearrangement with strong base [2], and Sommelet–Hauser rearrangement with base [3]. The quaternary ammonium salts containing perfluoroalkyl group(s) are expected to have chemical reactivities different from those of the fluorine-free counterparts. Although some perfluoroalkylated ammonium salts have been synthesized and used practically [4], there are few or no investigations on the reactions of these salts. We recently reported the synthetic method and surface activities for (1*H*,1*H*,ω*H*-perfluoroalkyl)trimethylammonium iodides (**1**), $R_fCF_2CH_2N^+Me_3I^-$, and showed that they were extremely stable under neutral or acidic conditions [5]. In this paper, we wish to describe the unique reaction between these fluorine-containing ammonium salts and sodium hydroxide.

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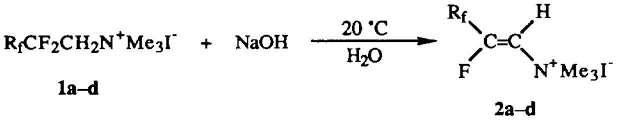
RESULTS AND DISCUSSION

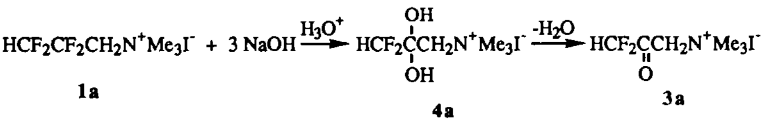
The ammonium salts **1a–d** were allowed to react with an equimolar amount of sodium hydroxide in water at 20 °C for 2 h to afford only *Z* isomers of (1*H*,ω*H*-perfluoro-1-alkenyl)trimethylammonium iodides (**2a–d**), $R_fCF{=}CHN^+Me_3I^-$, in quantitative yields (eq. 1). The configurational assignment of **2** was made on the basis of the magnitude (22.8–26.0 Hz) of the coupling constants between a vinylic hydrogen and fluorine. The chain length of the R_f group in **1** did not affect the yields or the stereochemistry of the products **2**.



(1)

a: $R_f = HCF_2$, **b**: $R_f = CF_3$, **c**: $R_f = H(CF_2)_3$, **d**: $R_f = H(CF_2)_5$

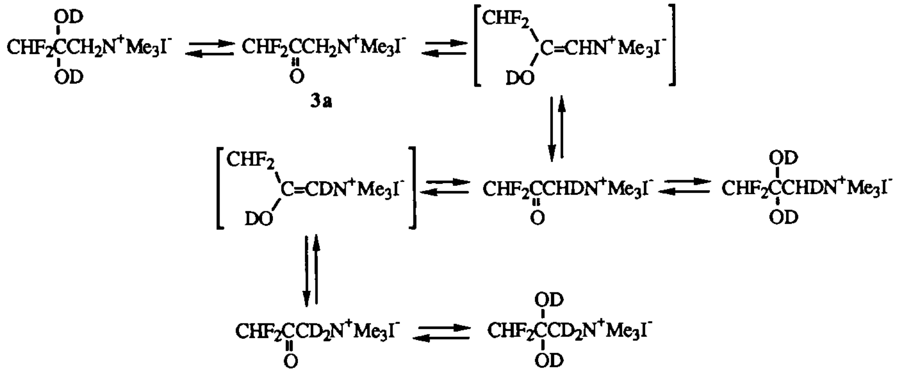
The reaction of **1a** with 3 equimolar amounts of sodium hydroxide in water at 20 °C for 2 h afforded (3,3-difluoro-2,2-dihydroxypropyl)trimethylammonium iodide (**4a**) quantitatively after acidification with hydrochloric acid followed by removal of water. The isolated **4a** was dehydrated without any decomposition by heating at 70 °C under vacuum (< 1 mmHg) to give (2-oxo-3,3-difluoropropyl)trimethylammonium iodide (**3a**) (eq. 2). When **1a** was exposed to 2 equimolar amounts of sodium hydroxide, **2a** and **4a** were obtained in a ratio of 1:1. Treatment of **2a** with 2 equimolar amounts of sodium hydroxide provided **4a** in quantitative yield. Thus, the complete reaction of **1a** was found to proceed through **2a** and to necessitate at least 3 equimolar amounts of sodium hydroxide. The structures of **3a** and **4a** were determined by ^1H, ^{13}C, ^{19}F NMR (Table 1), IR, and mass spectra.



$$\underset{\mathbf{1a}}{HCF_2CF_2CH_2N^+Me_3I^-} + 3\,NaOH \xrightarrow{H_3O^+} \underset{\mathbf{4a}}{HCF_2\overset{OH}{\underset{OH}{C}}CH_2N^+Me_3I^-} \xrightarrow{-H_2O} \underset{\mathbf{3a}}{HCF_2\underset{O}{\overset{}{\underset{\|}{C}}}CH_2N^+Me_3I^-} \quad (2)$$

The ^{19}F NMR spectra of **3a** in dried dimethyl sulfoxide-d_6 (DMSO-d_6) showed only one doublet due to the difluoromethyl group at -51.0 ppm (J_{HF} = 52.8 Hz). On adding a small amount of water to the above NMR sample, a new doublet appeared at -54.7 ppm (J_{HF} = 54.8 Hz) in addition to the doublet due to **3a**. In sufficiently wetted DMSO-d_6 or in deuterium oxide (D_2O), the doublet due to **3a** disappeared and the new doublet was observed alone. The ^{13}C NMR analysis of **3a** also showed a similar phenomenon: The resonance due to carbonyl carbon was detected as triplet (J_{CF} = 22.4 Hz) at 190.4 ppm in dried DMSO-d_6 but not in wetted DMSO-d_6 nor in D_2O. Moreover, the IR spectra of **3a** in wetted DMSO-d_6 or D_2O exhibited no absorption of carbonyl group. Such spectral data for **3a** in aqueous media including ^1H NMR were in good accord with those of the hydrate **4a**. These observations clearly indicate that **3a** has a great tendency to form the hydrate. This tendency has recently been found in β-keto esters [6], such as 2-hydro-3-oxoperfluoroesters, which have electron attractive atoms or groups on the α- or β-carbon.

The keto–enol equilibrium of β-keto esters has been well studied and their enol contents shown to depend upon the nature of the α- and β-substituents [7]. Recent reports demonstrate that the enol contents of perfluoroacylacetates are very high [8] whereas the α-fluoro analogs exist largely as the keto form [6,9]. The enol form of compound **3a** was not detected in the solid state nor in a solution in DMSO under neutral conditions. However, it was found that deuterium exchange of the α-methylene hydrogens of **3a** occurred in D_2O under neutral or weakly acidic conditions. This may reasonably be explained in terms of the following process (Scheme 1) where a transient enolic compound is involved through the reversible interconversion of **3a**.



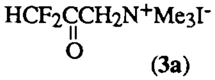
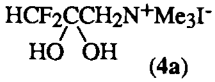
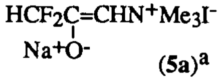
Scheme 1

The reaction mixture of **1a** with sodium hydroxide (3 equimolar amounts) was subjected to the ^{19}F NMR analyses prior to acidification. Two doublets due to the difluoromethyl group were observed at -42.0 ppm (J_{HF} = 55.6 Hz) and -54.7 ppm (J_{HF} = 54.8 Hz) in a ratio of near

1:1. When this reaction mixture was acidified with hydrochloric acid, the doublet at lower field (-42.0 ppm) disappeared whereas the doublet at higher field (-54.7 ppm) was intensified. In turn, the addition of sodium hydroxide to this acidified solution regenerated the original two doublets. The compound corresponding to the doublet at higher field was isolated and identified as the hydrate **4a**. All attempts to isolate the compound **5a** corresponding to the doublet at lower field were unsuccessful. However, careful examination of its ^1H, ^{19}F, and ^{13}C NMR spectra (Table 1) allowed us to assign to the compound **5a** the structure of the enolate form of **3a**. It should be noted that this compound **5a**, easily converted into **4a** with aqueous acid, could be produced by simple treatment of compound **3a** with sodium hydroxide. These facts also support the present structural assignment. Compound **3a** exists mainly as the enolate form **5a** in an aqueous basic solution and as the hydrate form **4a** in an aqueous neutral or acidic solution.

TABLE 1

NMR Spectral Data for the Ammonium Salts **3a**, **4a**, and **5a** in DMSO-d_6

Compound	^1H NMR	^{19}F NMR	^{13}C NMR
 $HCF_2\underset{\underset{O}{\|}}{C}CH_2N^+Me_3I^-$ (**3a**)	3.23 (9H, s)	-51.0 (d, *J* = 52.8)	53.6 (s)
	4.99 (2H, s)		66.1 (s)
	6.35 (1H, t, *J* = 52.8)		108.6 (t, *J* = 245.5)
			190.4 (t, *J* = 22.4)
 $HCF_2\underset{HO\ \ OH}{C}CH_2N^+Me_3I^-$ (**4a**)	3.23 (9H, s)	-54.7 (d, *J* = 54.8)	55.7 (s)
	3.50 (2H, s)		65.3 (s)
	5.69 (1H, t, *J* = 54.8)		92.7 (t, *J* = 22.7)
	7.22 (2H, s)		114.5 (t, *J* = 246.9)
 $HCF_2\underset{\underset{Na^+O^-}{\|}}{C}{=}CHN^+Me_3I^-$ (**5a**)[a]	3.55 (9H, s)	-42.0 (d, *J* = 55.6)	55.6 (s)
	5.19 (1H, s)		106.0 (s)
	5.73 (1H, t, *J* = 55.6)		113.6 (t, *J* = 241.9)
			156.4 (t, J = 20.4)

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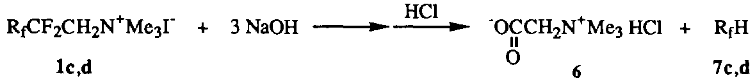
[a] The NMR analyses were performed in a solution of DMSO-d_6 containing aqueous sodium hydroxide.

The reaction of (2,2,3,3,3-pentafluoropropyl)trimethylammonium iodide (**1b**) with 3 equimolar amounts of sodium hydroxide was carried out in water at 20 °C. The ^{19}F NMR spectrum of the reaction mixture showed two singlets at 5.6 ppm and -5.7 ppm in a ratio of 1:2, which were due to the enolate and the hydrate form of (2-oxo-3,3,3-trifluoropropyl)trimethylammonium iodide (**3b**), respectively. On acidifying this mixture with hydrochloric acid followed by evaporation of water under reduced pressure, the corresponding hydrate **4b** and betaine **6** were obtained in 70% and 20% yields, respectively. Similar results were obtained from the reaction between (2,3,3,3-tetrafluoro-1-propenyl)trimethylammonium iodide (**2b**) and 2 equimolar amounts of sodium hydroxide. The hydrate **4b** could not be converted into the ketonic compound **3b**, even after long heating at higher temperatures under vacuum. Reaction of **1b** with 4 equimolar amounts of sodium hydroxide afforded betaine **6** quantitatively, no **4b** being present.



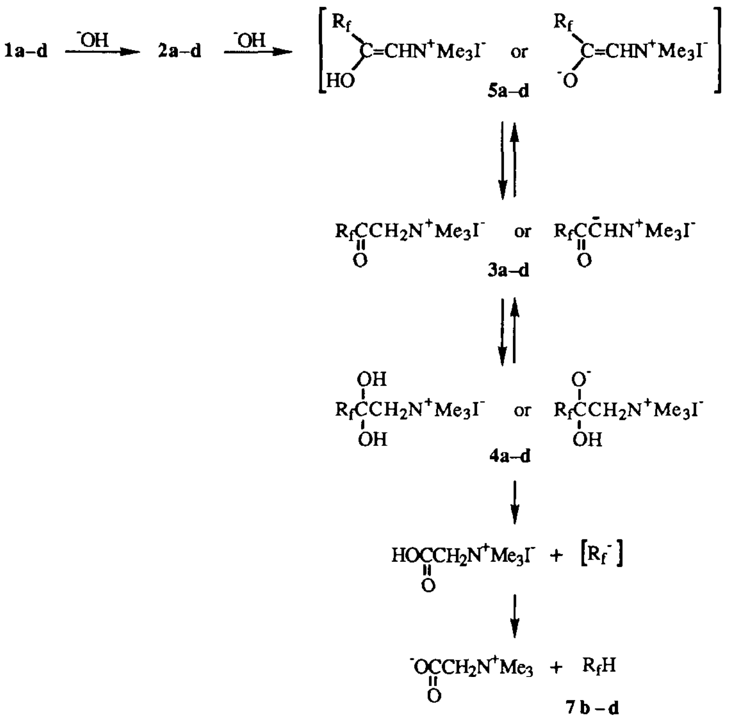
$$R_fCF_2CH_2N^+Me_3I^- \; + \; 3\,NaOH \xrightarrow{HCl} {}^-O\underset{\underset{\displaystyle O}{\|}}{C}CH_2N^+Me_3\,HCl \; + \; R_fH \qquad (3)$$

1c,d **6** **7c,d**

c: $R_f = H(CF_2)_3$, **d**: $R_f = H(CF_2)_5$

Treatment of (2,2,3,3,4,4,5,5-octafluoropentyl)trimethylammonium iodide (**1c**) with 3 equimolar amounts of sodium hydroxide in water at 20 °C gave betaine **6** in 95% yield. When the reaction of (2,2,3,3,4,4,5,5,6,6,7,7-dodecafluoroheptyl)trimethylammonium iodide (**1d**) was conducted under the same conditions, 1,1,2,2,3,3,4,4,5,5-decafluoropentane (**7d**) was isolated in high yield, in addition to **6** (eq. 3). Failure to isolate 1,1,2,2,3,3-hexafluoropropane (**7c**) in the former reaction is attributable to its low boiling point and high volatility.

A striking contrast to the reactions of **1a** and of **1b** is that the reactions of **1c** or **1d** with sodium hydroxide did not afford (2,2-dihydroxy-1*H*,1*H*,ω*H*-perfluoroalkyl)trimethylammonium iodide (**4c** or **4d**) or (2-oxo-1*H*,1*H*,ω*H*-perfluoroalkyl)trimethylammonium iodide (**3c** or **3d**). This may be ascribed to the hydrates **4c** and **4d** carrying a long perfluoroalkyl chain being more labile than **4a** and **4b** carrying a short perfluoroalkyl chain, the behaviour of **4** under basic conditions being related to the stabilities of the corresponding polyfluoroalkyl anions (R_f^-). In this connection, Andreades has demonstrated [10] that a perfluoroalkyl group more greatly facilitates the formation of carbanion at the adjacent position than a fluorine atom does. Thus, the enol or enolate **5** generated in the reaction would be in equilibrium with the keto form **3**, which undergoes facile hydration to yield the hydrate **4**, as depicted in Scheme 2. Under the present reaction conditions, in particular, **4c** and **4d** may decompose via a haloform like-reaction process to liberate **7c** and **7d** together with betaine.



Scheme 2

EXPERIMENTAL

Infrared spectra (IR) were recorded on a Shimadzu IR-400 and/or FTIR-800 infrared spectrometer. ^{1}H and ^{13}C NMR spectra were obtained with a Varian XL-200 (^{1}H, 200 MHz; ^{13}C, 50 MHz) spectrometer in DMSO-d_6 or deuteriochloroform ($CDCl_3$) with tetramethylsilane (TMS) as an internal reference or in D_2O with sodium 2,2-dimethyl-2-silapentane-5-sulfonate (DSS) as an external standard. A Hitachi R-24F (56.466 MHz) spectrometer was used to measure ^{19}F NMR spectra in DMSO-d_6, $CDCl_3$, or D_2O with trifluoroacetic acid (TFA) as an external reference. Mass spectra (MS) were taken on a Hitachi M-80B mass spectrometer by using the method of secondary ion mass spectra (SIMS). All chemicals were of reagent grade and, if necessary, were purified by conventional methods. The starting (1*H*,1*H*,ω*H*-perfluoroalkyl)trimethylammonium iodides (**1a–d**) were prepared in good yields according to our method reported previously [5].

Reaction of **1a–d** with an equimolar amount of sodium hydroxide

To a stirred solution of 10 mmol of (2,2,3,3-tetrafluoropropyl)trimethylammonium iodide (**1a**) in 20 mL of water was slowly added 10 mL (10 mmol) of 1M aqueous sodium hydroxide solution. The mixture was stirred at 20 °C for 2 h. Then, water was removed under reduced pressure to leave a white solid, to which was added 50 mL of acetone. After the whole mixture was stirred for several minutes at ambient temperature, insoluble solid (NaF) was filtered off. The filtrate was concentrated under reduced pressure to give crude (2,3,3-trifluoro-1-propenyl)trimethylammonium iodide (**2a**), which was purified by recrystallization from acetone–pentane (1:1) or column chromatography on silica gel using benzene as eluent to afford analytically pure salt as a colorless solid in 97% yield.

The reactions between **1b–d** and sodium hydroxide were conducted in the same manner as described above, the corresponding (polyfluoro-1-alkenyl)trimethylammonium iodides (**2b–d**) being obtained in almost quantitative yields. All are new compounds.

(2,3,3-Trifluoro-1-propenyl)trimethylammonium iodide (**2a**)

97% yield; Mp 121–122 °C; IR (KBr) 1732 cm^{-1} (C=C); ^{1}H NMR (D_2O, DSS) δ 3.56 (9H, s), 6.45 (1H, dt, *J* = 3.9, 51.4 Hz), 6.71 (1H, d, *J* = 26.0 Hz); ^{19}F NMR (D_2O, TFA) δ -45.3 (1F, m), -47.4 (2F, dd, *J* = 3.9, 51.4 Hz); MS (SIMS) *m/z* 435, 154, 138, 58.

(2,3,3,3-Tetrafluoro-1-propenyl)trimethylammonium iodide (**2b**)

95% yield; Mp 148–150 °C; IR (KBr) 1742 cm^{-1} (C=C); ^{1}H NMR (D_2O, DSS) δ 3.63 (9H, s), 7.10 (1H, d, *J* = 24.4 Hz); ^{19}F NMR (D_2O, TFA) δ 5.9 (3F, d, *J* = 10.4 Hz), -51.0 (1F, dq, *J* = 24.4, 10.4 Hz); MS (SIMS) *m/z* 471, 172.

(2,3,3,4,4,5,5-Heptafluoro-1-pentenyl)trimethylammonium iodide (**2c**)

94% yield; Mp 114–115 °C; IR (KBr) 1731 cm^{-1} (C=C); ^{1}H NMR (D_2O, DSS) δ 3.69 (9H, s), 6.63 (1H, tt, *J* = 50.6, 5.0 Hz), 7.17 (1H, d, *J* = 26.0 Hz); ^{19}F NMR (D_2O, TFA) δ -40.2 (1F, m), -41.7 (2F, m), -51.2 (2F, m), -58.9 (2F, dm, *J* = 50.6 Hz); MS (SIMS) *m/z* 635, 254, 138, 58.

(2,3,3,4,4,5,5,6,6,7,7-Undecafluoro-1-heptenyl)trimethylammonium iodide (**2d**)

91% yield; Mp 101–103 °C; IR (KBr) 1724 cm^{-1} (C=C); ^{1}H NMR (D_2O, DSS) δ 3.72 (9H, s), 6.51 (1H, tt, *J* = 49.6, 5.3 Hz), 7.33 (1H, d, *J* = 23.6 Hz); ^{19}F NMR (D_2O, TFA) δ -40.2 (2F, m), -44.8 (4F, m), -51.8 (2F, m), -59.8 (2F, dm, *J* = 49.6 Hz); MS (SIMS) *m/z* 835, 354, 138, 58.

Reaction of **1a** with 3 equimolar amounts of sodium hydroxide

To a solution of 10 mmol of **1a** in 30 mL of water was slowly added 30 mL (30 mmol) of 1M aqueous sodium hydroxide. The mixture was stirred at 20 °C (ca. 2 h) until the starting ammonium salt was consumed (monitored by ^{19}F NMR). After completion of the reaction, the reaction mixture was acidified with 1M hydrochloric acid and successively concentrated to dryness under reduced pressure. The resulting white solids were dissolved in 50 mL of acetone and allowed to stir for several minutes. Insoluble solids (NaF and NaCl) were filtered off. The filtrate was concentrated to give almost pure (2,2-dihydroxy-3,3-difluoropropyl)trimethylammonium iodide (**4a**) in 92% yield. This ammonium salt was heated at 70 °C for 6 h under vacuum (< 1 mmHg) to afford (2-oxo-3,3-difluoropropyl)trimethylammonium iodide (**3a**).

The reaction of **2a** with 2 equimolar amounts of sodium hydroxide was performed in a similar manner, providing the product **4a** in 93% yield.

(2-Oxo-3,3-difluoropropyl)trimethylammonium iodide (**3a**) (nc)

Mp 174–176 °C (dec.); IR (KBr) 3025 (m), 2960 (m), 2885 (m), 1755 (C=O) (s), 1490 (m), 1395 (m), 1385 (m), 1165 (m), 1095 (s), 1060 (m), 965 (m), 940 (m), 910 (m), 675 (m) cm^{-1}; MS (SIMS) *m/z* 431, 152, 58.

(2,2-Dihydroxy-3,3-difluoropropyl)trimethylammonium iodide (**4a**) (nc)

Mp 167–169 °C (dec.); IR (KBr) 3530–3050 (OH) (br s), 2970 (w), 1490 (w), 1265 (m), 1150 (m), 1125 (m), 1095 (m), 1065 (s), 965 (m), 910 (m), 840 (m), 750 (m) cm^{-1}; MS (SIMS) *m/z* 467, 449, 431, 170, 152, 58.

Reaction of **1b** with 3 equimolar amounts of sodium hydroxide

To a solution of 10 mmol of **1b** in 30 mL of water was gradually added 30 mL (30 mmol) of 1M aqueous sodium hydroxide solution. This mixture was stirred at 20 °C for 2 h. Although a small amount of the starting ammonium salt still remained unchanged, the reaction was quenched with 1M hydrochloric acid. The resultant reaction mixture was treated according to the same procedure as cited above to provide (2,2-dihydroxy-3,3,3-trifluoropropyl)trimethylammonium iodide (**4b**), betaine **6**, and **1b** in 70%, 20%, and 10% yield, respectively.

The use of water–acetonitrile (1:1) as solvent resulted in complete consumption of the starting ammonium salt, leading to 63% yield of **4b** and 16% yield of **6**.

(2,2-Dihydroxy-3,3,3-trifluoropropyl)trimethylammonium iodide (**4b**) (nc)

Mp 161–163 °C (dec.); IR (KBr) 3550–3065 (OH) (br s), 2995 (w), 1480 (w), 1325 (m), 1245 (m), 1195 (s), 1175 (s), 1160 (s), 1135 (m), 1090 (s), 970 (m), 955 (m), 910 (m), 895 (m), 715 (m) cm^{-1}; ^{1}H NMR (DMSO-d_6) δ 3.39 (9H, s), 3.72 (2H, s), 8.25 (2H, s); ^{19}F

NMR (DMSO-d_6, TFA) δ -5.7 (s); ^{13}C NMR (DMSO-d_6) δ 54.9 (s), 63.2 (s), 92.1 (q, *J* = 31.0 Hz), 122.7 (q, *J* = 292.6 Hz).

Reaction of **1b** with 4 equimolar amounts of sodium hydroxide

The reaction of **1b** with 4 equimolar amounts of sodium hydroxide was conducted in a similar manner to that cited above. The ^{19}F NMR analysis of the reaction mixture after 2 h did not reveal any signals corresponding to the trifluoromethyl group, only a singlet due to fluoride ion being detected. Acidifying the reaction mixture with 1M hydrochloric acid, evaporation of water under reduced pressure, and recrystallization with ethanol, gave betaine **6** in quantitative yield.

Reaction of **1c** with 3 equimolar amounts of sodium hydroxide

The reaction of **1c** with 3 equimolar amounts of sodium hydroxide was carried out similarly. During the course of this reaction, the precipitation of sodium fluoride and the evolution of gas were observed. The reaction mixture was acidified with 1M hydrochloric acid and concentrated *in vacuo* to give crude solid, which was subjected to recrystallization with ethanol affording **6** in 95% yield.

Reaction of **1d** with 3 equimolar amounts of sodium hydroxide

The salt **1d** was treated with 3 equimolar amounts of sodium hydroxide under the same conditions as described above. As the reaction proceeded, the reaction mixture gradually separated into two phases. The lower oily phase was separated and dried over sodium sulfate to afford nearly pure 1,1,2,2,3,3,4,4,5,5-decafluoropentane (**7d**). Acidification of the upper aqueous phase followed by concentration to dryness and recrystallization yielded betaine **6** quantitatively.

1,1,2,2,3,3,4,4,5,5-Decafluoropentane (**7d**) (nc)

^{1}H NMR ($CDCl_3$) δ 5.98 (1H, tm, *J* = 52.4 Hz); ^{19}F NMR ($CDCl_3$, TFA) δ -47.3 (2F, m), -52.0 (4F, m), -59.8 (4F, dm, *J* = 52.4 Hz).

Betaine hydrochloride (**6**)

Mp 238–241 °C (lit. Mp 232 °C [11]); IR (KBr) 3400 (br m), 2960 (w), 1620 (s), 1485 (m), 1420 (s), 1395 (s), 1345 (s), 980 (m), 940 (m), 895 (s), 720 (m) cm^{-1}; ^{1}H NMR (D_2O) δ 3.26 (9H, s), 3.90 (2H, s), 4.53 (1H, s).

REFERENCES

1 A. W. Hofmann, Chem. Ber., *14* (1881) 659; for a review, A. C. Cope and E. R. Trumbull, Org. React., *11* (1960) 317.

2 (a) T. S. Stevens, E. M. Creighton, A. B. Gordon, and M. McNicol, J. Chem. Soc., (1928) 3193; (b) For a review, S. H. Pine, Org. React., *18* (1970) 403.

3 M. Sommelet, Compt. Rend., *205* (1937) 56; S. W. Kantor and C. R. Hauser, J. Am. Chem. Soc., *73* (1951) 4122; for a review, see 2b.

4 For example, R. A. Falk, U.S. Pat. 4 420 434 (1983); T. Kunitake and N. Higashi, J. Am. Chem. Soc., *107* (1985) 692.

5 H. Yamanaka, H. Kanbayashi, M. Kuwabara, K. Fukunishi, and M. Nomura, Nippon Kagaku Kaishi, (1988) 1036.

6 M. Iznaden and C. Portella, J. Fluorine Chem., *43* (1989) 105.

7 J. L. Burdett and M. T. Rogers, J. Am. Chem. Soc., *86* (1964) 2105.

8 V. Bayer, R. Pastor, and A. Cambon, J. Fluorine Chem., *20* (1982) 187.

9 M. Iznaden and C. Portella, Tetrahedron Lett., *29* (1988) 3683.

10 S. Andreades, J. Am. Chem. Soc., *86* (1964) 2003.

11 R. Richard and H. W. Ruelius, Ber., *83* (1950) 420.