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Studies on Organic Fluorine Compounds. IV.[1] Conversion of Alcohols to Fluorides by Diphenyltrifluorophosphorane

Yoshiro Kobayashi,[2,3a] Chigen Akashi,[3b]
and Kunio Morinaga[3a]

Tokyo College of Pharmacy[3a] *and Research Laboratories,*
Yawata Chemical Industry Co., Ltd.[3b]

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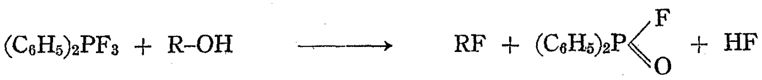
The reactions of diphenyltrifluorophosphorane with alcohols were studied, and it was found to be a more excellent one-step fluorinating reagent for substituting the hydroxyl group of alcohols. Compared with difluorotriphenylphosphorane discussed in the previous paper, this reagent is superior in its being able to be produced at less cost and its reaction starting at the lower temperature. The reaction mechanism when solvent was used is presumed to be the same as in the case of difluorotriphenylphosphorane, but reaction modes differ when solvent was not used. To use solvent is better for preparing alkyl fluoride.

In the previous paper,[1] we reported that difluorotriphenylphosphorane ($(C_6H_5)_3PF_2$) was found to be an available one-step fluorinating reagent for substituting the hydroxyl group of alcohols. Schmutzler investigated into the stereochemistry and nuclear magnetic resonance (NMR) spectra of fluorophosphoranes (R_nPF_{5-n}); in his papers he refers to diphenyltrifluorophosphorane and phenyltetrafluorophosphorane, and a little mention is made of their reactivity though nothing is said about the reaction with alcohols.[4,5]

Considering the result of our previous paper, we took interest in comparing the reactivities of a series of these compounds with alcohols. In this paper we report that the reaction of diphenyltrifluorophosphorane with alcohols was carried out, and that diphenyltrifluorophosphorane was found to be a still more excellent fluorinating reagent than difluorotriphenylphosphorane. There are two ways for preparing the reagent; one is to treat diphenylphosphinic acid with sulfurtetrafluoride[6] and the other is to treat chlorodiphenlyphosphine with arsenic trifluoride or antimonic trifluoride.[4] By conducting all the ways, we found the method with antimonic trifluoride to be economically far more advantageous, for it is available inexpensively in this country.

When the first method, that of Smith, was used, diphenyltrifluorophosphorane was given in a far better yield (93%) than in the literature (42%), by prolonging the heating time.

Concerning the reaction of the reagent with alcohols, we presume that, when more than one mole equivalent of the reagent was used, it followed the formula below, similar to the case of difluorotriphenylphosphorane.



$$(C_6H_5)_2PF_3 + R\text{-}OH \longrightarrow RF + (C_6H_5)_2P\begin{matrix}\diagup F\\ \diagdown O\end{matrix} + HF$$

We first chose *n*-octyl alcohol as representative and examined the effect on the yield of *n*-octyl fluoride of the following conditions, always using two mole equivalents of the

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[1] Part III: Y. Kobayashi and C. Akashi, *Chem. Pharm. Bull.* (Tokyo), **16**, 1009 (1968).

[2] All communication and requests are to be sent to this author.

[3] Location: *a*) *Kashiwagi, Shinjuku-ku, Tokyo*; *b*) *Nakabaru, Tobata-ku, Kitakyushu-shi.*

[4] R. Schmutzler, *Inorg. Chem.*, **3**, 410 (1964).

[5] R. Schmutzler, *Angew. Chem.*, **77**, 530 (1965).

[6] W.C. Smith, *J. Am. Chem. Soc.*, **82**, 6176 (1960).

reagent to the alcohol: with acetonitrile as solvent in various reaction temperatures, without solvent in various reaction temperatures, and without solvent in various reaction times. As the result, we found that the reaction mode extremely varies according to the presence or absence of the solvent. The reaction was carried out in a stainless steel reaction tube and the yields of products based on alcohol were derived from gas chromatographic analysis of the benzene solution obtained by adding benzene to the reaction mixture and working up with alkali.

TABLE I

No.	Reagent/Alcohol (mol. ratio)	Temp. (°C)	Time (hr)	Yield of product (%)	
				n–Octyl fluoride	1–Octene
1	2.05	80	10	13.5	—
2	1.83	100	10	25.4	trace
3	1.84	120	10	31.0	trace
4	1.84	150	10	52.8	3.1
5	1.85	170	10	75.7	7.3

solvent–CH_3CN

As shown in Table I, the yield of *n*–octyl fluoride increased as the reaction temperature was made higher, when solvent was used. The yield of 1–octene increased, too, but the amount was very small compared with that of alkyl fluoride. With this reagent, alkyl fluoride could be obtained at the reaction temperature as low as 80°, though its yield was not so good; besides, 1–octene was not produced, thereby making it more widely applicable than difluorotriphenylphosphorane, which required the reaction temperature higher than 140° to start the reaction. For this reason as well as the economic one mentioned before, this reagent is superior.

TABLE II

No.	Reagent/Alcohol (mol. ratio)	Temp. (°C)	Time (hr)	Yield of product (%)	
				n–Octyl fluoride	1–Octene
6	1.96	80	10	23.1	3.2
7	2.00	100	10	38.5	8.8
8	2.06	120	10	37.2	24.4
9	2.05	140	10	42.0	29.4
10	1.86	160	10	21.0	37.4

without solvent

TABLE III

No.	Reagent/Alcohol (mol. ratio)	Temp. (°C)	Time (hr)	Yield of product (%)	
				n–Octyl fluoride	1–Octene
11	2.18	120	2	45.2	18.3
12	2.12	120	4	40.4	21.5
13	2.06	120	6	38.9	24.6
14	2.00	120	8	40.4	24.3
15	2.06	120	10	37.2	24.4

without solvent

Without solvent, the yield of *n*–octyl fluoride was better when the reaction temperatures were 100°, 120°, and 140° than when it was 80°, but the yield dropped at 160°, as shown in Table II. As for 1–octene, its yield increased as the temperature was raised, and at 160° it predominated over that of octyl fluoride. In the case where the reaction temperature was set constant without solvent, the yield of *n*–octyl fluoride slightly decreased as the reaction time was made longer, as shown in Table III. On the contrary, the yield of 1–octene tended to increase until six hours; from that time on it remained constant.

From the above experimental results, it may be presumed that 1–octene was produced by decomposition of *n*–octyl fluoride; but, as the peak corresponding to 1–octene was not detected on gas chromatogram when *n*–octyl fluoride was treated in the same conditions as above (one mole equivalent each of *n*–octyl fluoride, diphenyltrifluorophosphorane, and hydrogen fluoride were heated at 160° for ten hours without solvent), 1–octene must have been produced through a different mechanism.

As in the case of difluorotriphenylphosphorane, we carried out reactions of diphenyltrifluorophosphorane with the representatives of primary, secondary, and ω–substituted alcohols. In a stainless steel reaction tube, with acetonitrile as solvent, alcohol and the reagent (more than two mole equivalents to alcohol) were heated at 150° for ten hours with stirring. To the reaction mixture benzene was added, and the benzene layer was washed with alkali and water and distilled after drying. The result is shown in Table IV. The yield of the products were obtained from the gas chromatography of the benzene layer. The yields of alkyl fluorides could be made better, since the reaction conditions for each kind of alcohol we used were not optimum. Dimethylformamide was also found to be an available solvent.

In every case, a small peak of what seemed to be olefins was shown on the gas chromatogram. Though the reaction can be carried out in a glass apparatus with the presence of tertiary amines to neutralize the generating hydrogen fluoride, the loss is smaller with a reaction tube. The products were purified using preparative gas chromatography, and as in the cases in the previous paper, identified by comparing with the authentic samples synthesized in other ways as to their infrared (IR) spectrum, refractive index, and retention time of gas chromatography.

TABLE IV

Alcohol	Main product	Yield (%)
n–Octyl–	*n*–$CH_3(CH_2)_7F$	75.7[a]
n–Amyl–	*n*–$CH_3(CH_2)_4F$	62.2
Benzyl–	$C_6H_5CH_2F$	31.8
Phenethyl–	$C_6H_5CH_2CH_2F$	51.5
3–Chloropropyl–	$ClCH_2CH_2CH_2F$	64.1
sec–Amyl–	$CH_3CH_2CH_2CHFCH_3$	54.3

a) Reaction temperature was 170° in this case.

As this reagent and its reaction products are liable to be toxic, caution should be used not to touch or inhale them directly.

Experimental

Diphenyltrifluorophosphorane——A) In a 100 ml Hastelloy–C–lined autoclave, diphenylphosphinic acid (80.0 g, 0.37 mole) and SF_4 (88.6 g, 0.82 mole) were heated at 150° for 12 hr. After the reaction was completed, unchanged SF_4 was discharged, and then all the gas was completely eliminated *in vacuo*. Then the remaining dark brown liquid was distilled *in vacuo*. A yellow liquid (bp 116—117° (3 mmHg)) was obtained in 93.8% yield.

B) To Ph_2PCl (49.0 g, 0.22 mole) SbF_3(56.0 g, 0.31 mole) was added in five portions with vigorous stirring. It was a slightly exothermic reaction, but cooling was not necessary. After warming it at 60° for 5 hr, the reaction mixture was distilled *in vacuo* with N_2 current. $SbCl_3$ was distilled first at 120°/18 min, and then Ph_2PF_3 (bp 135° (4 mmHg), 22.8 g) was obtained.

General Procedure of the Diphenyltrifluorophosphorane-alcohol Reaction——In a stainless steel reaction tube, freshly distilled Ph_2PF_3 (10.2 g, 0.042 mole), alcohols (0.019 mole with *n*-amyl alohol, 1.67 g), and CH_3CN (30 ml) were heated at 150° for 10 hr with stirring. After cooling to room temperature, the reaction mixture was removed into a separating funnel, and benzene (30 ml) was added. The benzene layer was washed with 30% NaOH and H_2O, and distilled after drying with Na_2SO_4.

The yields of the products were obtained by gas chromatographic analysis of the benzene layer.

The alkyl fluoride was obtained as main product (with *n*-amyl fluoride, 1.06 g), which was purified using preparative gas chromatography. The product was identified with the authentic sample prepared in the same manner as described in the previous paper.

The gas chromatographic analysis was also carried out, using the same apparatus under the same conditions as in the previous paper.

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