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N-Cyano-*N*,*N*,*N*-trialkylammonium Salts. Synthesis and Reactions

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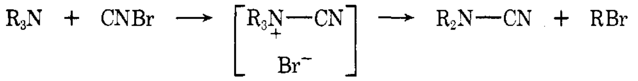
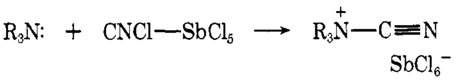
Stable *N*-cyano-*N*,*N*,*N*-trialkylammonium fluoroborates have been prepared and their reactivity examined. With nucleophiles there are at least two types of reactions—the alkylation reaction observed by von Braun and the cyanation reaction observed for the first time on stable *N*-cyanoammonium salts. The alkylation reaction proceeds with arylamines such as *N*-methylaniline and some other weak nucleophiles such as DMF. With strong nucleophiles such as isobutylamine, benzenethiol, and triphenylphosphine the reaction proceeds by cyanation, giving a variety of NuCN derivatives which react further in different ways.

N-Cyanoammonium bromides have been postulated as reactive intermediates in the von Braun reaction of tertiary amines and cyanogen bromide.[2] The reaction, discovered by von Braun[2] and independently by Scholl and Noerr,[3] has been extensively studied as a method of degrading tertiary amines to secondary cyanamides.[4,5] In his pioneering work on the cyanogen bromide reaction, von Braun[2] proposed that the nitrogen atom of a tertiary amine attacks cyanogen bromide to form bromide ion and *N*-cyano-*N*,*N*,*N*-trialkylammonium ion. The cation of the intermediate is subsequently attacked by bromide ion to form a dialkylcyanamide and an alkyl bromide.



$$R_3N + CNBr \longrightarrow \left[\begin{array}{c} R_3\underset{+}{N}\text{—}CN \\ Br^- \end{array}\right] \longrightarrow R_2N\text{—}CN + RBr$$

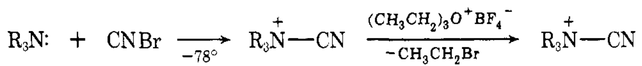
Concurrent with our report of the preparation of *N*-cyano-*N*,*N*,*N*-trialkylammonium fluoroborates,[6] Fodor and Abidi reported the characterization of the 1:1 adducts of cyanogen bromide and tertiary amines stabilized as tosylates.[7] It was also reported that the *N*-cyano-*N*,*N*,*N*-trialkylammonium hexachloroantimonates were prepared using antimony pentachloride–cyanogen chloride complex as shown below.



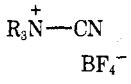
$$R_3N\!: + CNCl\text{—}SbCl_5 \longrightarrow \underset{SbCl_6^-}{R_3\overset{+}{N}\text{—}C\equiv N}$$

Fodor and Abidi subsequently reported an nmr spectroscopic kinetic study of the reaction of excess cyanogen bromide and *N*-methyldecahydroquinoline.[7] The kinetic data were explained by the fast formation of the intermediate *N*-cyanoammonium ion followed by its rate-determining decomposition to the cyanamide and methyl bromide.

The data available led us to believe that the primary reason for the instability of this class of compounds is the nucleophilic attack by the anion to regenerate the original reactants or to cleave an alkyl group. To stabilize the unstable cations, halide ion was replaced by other, less nucleophilic, anions such as fluoroborate anion.[8] To provide a source of fluoroborate under anhydrous conditions, a forcing anion exchange reaction was devised whereby the undesired anions were removed by alkylation with triethyloxonium fluoroborate.[9] Using an equivalent amount of triethyloxonium fluoroborate, the fluoroborate salts were obtained in pure forms, and were further purifiable by recrystallization. Some of the compounds prepared by this method have been previously reported in preliminary form.[6] In all cases the compounds had structures 1 or 2, showed sharp melting points, and were readily soluble in polar organic solvents. The compounds showed weak absorptions at 2260–2270 cm^{-1} which were different from those of cyanogen bromide[10] and, based on the increased frequency and decreased intensity, were consistent with the presence of a *N*-cyanoammonium fluoroborate.[11-15] The nmr spectra differed from those of the corresponding tertiary or quaternary ammonium fluoroborates. The combined physical and spectral data suggested that the compounds were *N*-cyanoammonium fluoroborates.



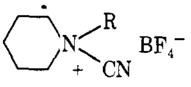
$$R_3N\!: + CNBr \xrightarrow[-78^\circ]{} \underset{Br^-}{R_3\overset{+}{N}\text{—}CN} \xrightarrow[-CH_3CH_2Br,\ -(CH_3CH_2)_2O]{(CH_3CH_2)_3O^+BF_4^-} \underset{BF_4^-}{R_3\overset{+}{N}\text{—}CN}$$



$$\underset{BF_4^-}{R_3\overset{+}{N}\text{—}CN}$$

1

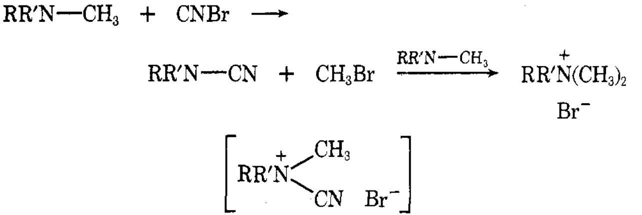
R = Et, Bu, Hex



2

R = Me, Et, Pr, Bu

The use of triethyloxonium fluoroborate was not universally applicable and met with failures when too reactive or too unreactive tertiary amines were used. Trimethylamine and *N*,*N*-dimethylcyclohexylamine reacted very rapidly to give only tetraalkylammonium salts as the sole solid products. This type of reaction has been observed with tertiary amines having *N*-methyl groups in the von Braun cyanogen bromide reaction.[16] Although the quaternization reaction has been assumed to occur by the alkylation of the formed methyl bromide, it may also proceed by the alkylation of the intermediate *N*-cyanoammonium bromide. In the other extreme, when the tertiary amine was not reactive enough at low temperature, neither an increase of the reaction temperature nor the addition of triethyloxonium fluoroborate to the partially formed adducts gave any desired products. This type of failure was observed with hindered tertiary amines such as diisopropylethylamine or dicyclohexylethylamine or with aromatic amines such as *N*,*N*-dimethylaniline. *N*-Benzylpiperidine and pyridine failed to give the expected products.

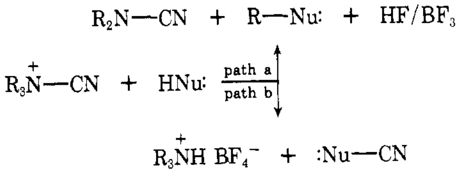


$$RR'N\text{—}CH_3 + CNBr \longrightarrow$$

$$RR'N\text{—}CN + CH_3Br \xrightarrow{RR'N\text{—}CH_3} \underset{Br^-}{RR'\overset{+}{N}(CH_3)_2}$$

$$\left[RR'\overset{+}{N}\begin{array}{l} CH_3 \\ CN \end{array} Br^-\right]$$

It is theoretically possible that a nucleophile can attack either on the alkyl groups (path a) or on the cyano group (path b). Since path a is similar to the originally suggest-



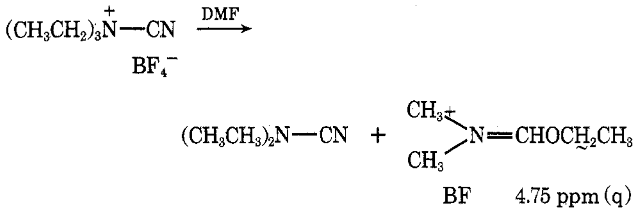
$$R_2N\text{—}CN + R\text{—}Nu\!: + HF/BF_3$$

$$R_3\overset{+}{N}\text{—}CN + HNu\!:\ \begin{array}{c} \text{path a}\uparrow \\ \text{path b}\downarrow \end{array}$$

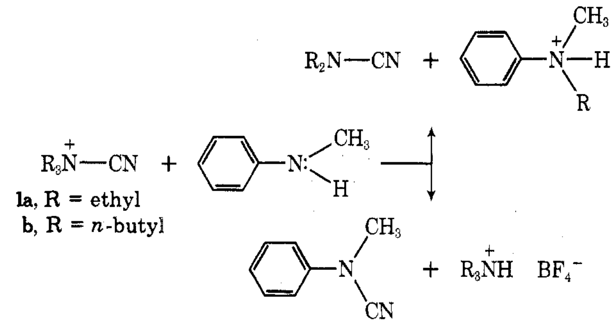
$$R_3\overset{+}{N}H\ BF_4^- + :Nu\text{—}CN$$

ed mechanism of the von Braun cyanogen bromide reaction, the *N*-cyanoammonium salts were expected to be good alkylating reagents. Path b might also be quite possible considering that the cyano group is bonded to a highly electron-withdrawing tertiary ammonium group.

To test the reactivity of *N*-cyanoammonium fluoroborates a small amount of a nucleophilic reagent, dimethylformamide or some other reagent, was added to an nmr sample tube containing a solvent and the *N*-cyanoammonium fluoroborate; this was placed in a spectrometer; spectral changes were observed during the first 1 or 2 hr. For dimethylformamide a quartet was observed at about δ 4.02 ppm which disappeared as the time proceeded, and a new quartet gradually appeared at about δ 4.75 ppm. The reaction was explained as being due to the attack of the nucleophile on the ethyl group of the *N*-cyanoammonium fluoroborate as shown below. The half-lives of some *N*-cyanoammonium fluoroborates obtained by this method were as follows: *N*-cyano-*N*,*N*,*N*-triethylammonium fluoroborate, 35 min with 8 equiv of D_2O in CH_3CN, 11 min with about 4 equiv of DMF in CH_3CN; *N*-cyano-*N*,*N*,*N*-tri-*n*-butylammonium fluoroborate, 12 min with about 4 equiv of DMF in CH_3CN, about 10 min in dimethyl sulfoxide-d_6.

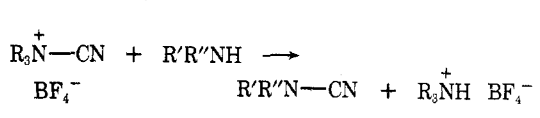


The nmr spectra of the ether-soluble products of reaction of *N*-cyanoammonium salts with *N*-methylaniline showed principally the presence of dialkylcyanamides derived from the *N*-cyanoammonium fluoroborates. A very small peak at δ 3.24 ppm, assigned to the *N*-methyl group of *N*-methylcyananilide, was detected and calculated to be less than 5%. The reaction thus occurred by nucleophilic attack on the alkyl groups of the *N*-cyanoammonium fluoroborates, which is in agreement with the pattern observed in the von Braun cyanogen bromide reaction. Diethylcyanamide (R = ethyl) and di-*n*-butylcyanamide (R = *n*-butyl) were obtained by distillation in 82 and 89% yield, respectively. The minor product, *N*-methylcyananilide, was obtained in low yields and identified by comparison with an authentic sample. The dialkylanilines were obtained in comparable yields to further substantiate the alkylation reaction.



1a, R = ethyl
b, R = *n*-butyl

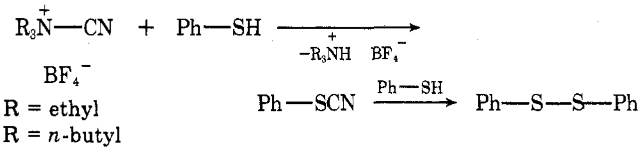
The exothermic reaction of the *N*-cyanoammonium fluoroborates with primary and secondary aliphatic amines proceeded to give exclusive cyano group cleavage. Thus the reaction of *N*-methylcyclohexylamine and isobutylamine gave in high yield with *N*-cyanoammonium salts the expected cyanamides, *N*-methylcyclohexylcyanamide and isobutylcyanamide, and the tertiary amine salts. It has been reported that cyanogen bromide, the only readily available cyanating reagent, could not be efficiently used for the cyanation of secondary and primary amines because of the formation of the amine hydrobromide salts, which often react with the cyanamides formed to yield guanidines.[17] The use of *N*-cyanoammonium fluoroborates as cyanating reagents for amines seems highly promising.



$$R_3\overset{+}{N}{-}CN \; BF_4^- + R'R''NH \longrightarrow R'R''N{-}CN + R_3\overset{+}{N}H \; BF_4^-$$

1a, R = ethyl
b, R = *n*-butyl
2c, R_3N = *N*-*n*-propylpiperidine

When a 1:1 molar ratio of *N*-cyano-*N*,*N*,*N*-triethylammonium fluoroborate and thiophenol were allowed to react, a small amount of phenyl disulfide and 67% of phenyl thiocyanate were obtained. When the *N*-cyano-*N*,*N*,*N*-tri-*n*-butylammonium fluoroborate and thiophenol were allowed to react in 1:2 molar ratio the yield of phenyl disulfide was 83% and the rest (11%) was phenyl thiocyanate. The reaction of *N*-cyanoammonium fluoroborates with thiophenol can be explained by the nucleophilic attack of thiol group on the cyano group only. The formation of phenyl disulfide can be ascribed to further reaction of the thiocyanate with unreacted thiol. The formation of disulfide by this scheme has been proposed as a very favorable path,[18] and recently alkyl disulfides were reported to be prepared by the reaction of thiols and cyanogen bromide directly.[19] Among other known methods alkyl thiocyanates have been prepared by the use of cyanogen bromide on lead or alkali metal mercaptides,[20] on thiols with an equivalent of tertiary amines,[21] or on dialkyl sulfides.[22,23]

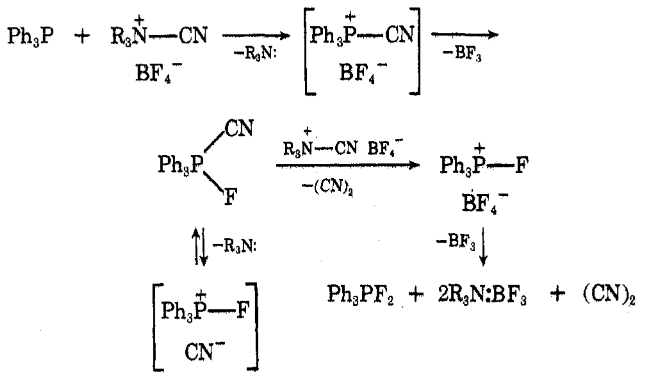


Sodium thiophenolate reacted with *N*-cyano-*N*,*N*,*N*-tri-*n*-butylammonium fluoroborate in 2:1 molar ratio to give 94% of relatively pure phenyl disulfide.

The reaction of *N*-cyanoammonium fluoroborate with triphenylphosphine in 1:1 molar ratio gave difluorotriphenylphosphorane in 51% yield. The yield was increased to about 93% when the *N*-cyanoammonium salt was used in 2:1 molar ratio. The reaction was exothermic at room temperature, and, since the product was not soluble in the reaction medium, it was obtained in good crystalline forms when the reaction mixture was allowed to cool to room temperature. The ^{19}F nmr spectrum of difluorotriphenylphosphorane agreed with that reported:[24] ^{19}F nmr (acetone, internal $CFCl_3$) δ 38.72 ppm (doublet), J_{P-F} = 665.2 Hz [^{19}F nmr ($CHCl_3$, internal $CFCl_3$) δ 40.4 ppm, J_{P-F} = 660 Hz]. The mass spectral fragmentation pattern could also be explained by the assigned structure.

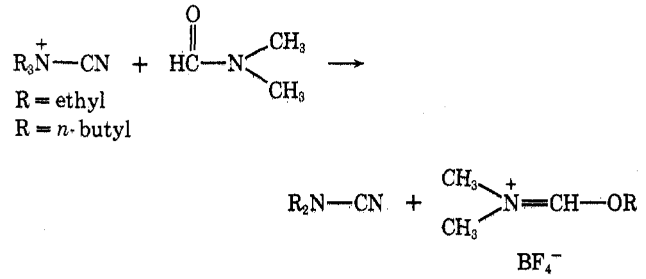
The reaction mechanism for the formation of difluorotriphenylphosphorane was not studied but a plausable pathway through the intermediacy of cyanotriphenylphosphonium fluoroborate,[25] fluorocyanotriphenylphosphorane, and fluorotriphenylphosphorium[26] cyanide can be devised. This pathway, as shown below, requires that dicyanogen and amine–BF_3 complex be major products in the reaction. We did not attempt to isolate dicyanogen but we did identify an amine–BF_3 complex as expected.

Difluorotriphenylphosphorane has been prepared in low yields (40–50%) by using sulfur tetrafluoride on triphenylphosphine or triphenylphosphine oxide in a pressurized

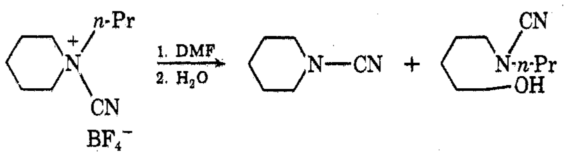


bottle at elevated temperature,[27a] or by fluorination of triphenylphosphine with tetrafluorohydrazine.[27b]

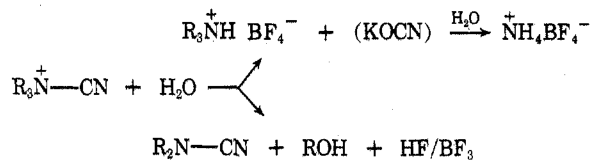
The reaction of *N*-cyanoammonium fluoroborates with dimethylformamide yielded only the alkyl group cleaved products. The dialkylcyanamides (R = ethyl and R = *n*-butyl) and dimethylammoniun fluoroborate obtained by hydrolyses were isolated in about 80% yield. No cyanation products of DMF were detected.



When *N*-cyano-*N*-*n*-propylpiperidinium fluoroborate was used in the reaction the alkyl group cleavage occurred in two ways as shown below. About 30% of piperidine cyanamide and 52% of 5-hydroxypentyl-*n*-propylcyanamide were obtained. This ratio corresponds to about 37% of the former and 63% of the latter, assuming that the alkyl group cleavage products were isolated in 100% yield. In the von Braun cyanogen bromide reaction of *N*-*n*-propylpiperidine the ratio of the propyl group cleavage product to the ring-cleavage product was 40:60.[28]



With water the cyano group cleavage product is cyanic acid. The detection of the formed cyanic acid was not attempted, but its hydrolysis product was obtained in about 15 and 14% yields, respectively, with the *N*-cyanoammonium salts (R = Et, R = Bu). The tertiary amine salts (R = ethyl and R = *n*-butyl) were obtained in 84% yields, indicating that the cyano group cleavage occurred at least to the extent of 84%. The dialkylcyanamides (R = ethyl and R = *n*-butyl) were obtained in 12 and 9% yields, respectively, from the alkyl group cleavage of the *N*-cyanoammonium salts. Ethanol was tentatively identified (nmr evidence) in the distillate of the reaction solvent of *N*-cyano-*N,N,N*-triethylammonium fluoroborate.



In summary, the cyanation reaction (path B) was observed with most strong nucleophiles such as aliphatic amines, thiophenol, sodium thiophenolate, triphenylphosphine, and water. The potential use of *N*-cyanoammonium salts as cyanating reagents in the reaction with carboxylic acids has been reported.[29] Alkyl-group cleavage (path A) was observed with dimethylformamide and *N*-methylaniline. The reasons for the highly selective reactions, either path A or path B, are not at all clear and require further study. It seems that *N*-cyanoammonium fluoroborates might not be useful as alkylating agents, contrary to original expectations, but may serve as versatile cyanating agents in a variety of reactions.

Experimental Section[30]

Preparation of *N*-Cyano-*N,N,N*-triethylammonium Fluoroborate. To a solution of 15 g (0.014 mol) of cyanogen bromide in 50 ml of ether cooled at −78° were added in small portions 10.1 g (0.10 mol) of triethylamine in 50 ml of ether cooled at −78°. Colorless crystals began to form immediately. The solution was stirred for 2 hr at −78° and 18.9 g (0.01 mol) of triethyloxonium *fluoroborate in 50 ml of dry methylene chloride cooled to* −78° was added at once. After stirred for several minutes the reaction mixture was allowed to warm up until room temperature was reached. The supernatant solvent was decanted from the colorless crystals under a dry nitrogen atmosphere and washed with 2:1 ether–methylene chloride mixed solvent three times. Drying *in vacuo* gave 20–21 g (93–98%) of *N*-cyano-*N,N,N*-triethylammonium fluoroborate. The product was recrystallized from acetonitrile by adding ethyl acetate: mp 63–64°; ir (Nujol mull) 2270 (weak, CN) and 1050–1100 cm^{-1}; nmr (acetone-d_6) δ 1.67 (t, CH_3, 9 H) and 4.30 (q, CH_2N^+, 6 H).

Anal. Calcd for $C_7H_{15}N_2BF_4$ (214.02): C, 39.28; H, 7.06; N, 13.09. Found: C, 39.12; H, 7.01; N, 13.27.

***N*-Cyano-*N,N,N*-tri-*n*-butylammonium fluoroborate** was prepared by the same procedure as that of *N*-cyano-*N,N,N*-triethylammonium fluoroborate with the extension of the time for the adduct formation to about 5 hr (97% yield) and was recrystallized from ethyl acetate by adding petroleum ether: mp 79–80°; ir (Nujol mull) 2265 (weak, CN) and 1050–1100 cm^{-1}; nmr (acetone-d_6) δ 1.01 (t, CH_3, 9 H), 1.27–1.77 (m, CH_2, 6 H), 1.83–2.40 (m, CH_2, 6 H), and 4.15–4.27 (m, CH_2N^+, 6 H); uv tail (acetonitrile) 240 nm (*E* 40).

Anal. Calcd for $C_{13}H_{27}N_2BF_4$ (298.19): C, 52.36; H, 9.13; N, 9.40. Found: C, 52.50; H, 9.17; N, 9.30.

***N*-Cyano-*N*-methylpiperidinium fluoroborate** was prepared by the same procedure as that of *N*-cyano-*N,N,N*-tri-*n*-butylammonium floroborate (86% yield): mp 83–85°; ir (Nujol mull) 2260 (weak, CN) and 1000–1100 cm^{-1}; nmr (acetonitrile) δ 3.81 (s, CH_3N^+, 3 H), and 3.70–4.76 (m, CH_2N^+, 4 H).

Anal. Calcd for $C_7H_{13}N_2BF_4$ (212.01); C, 39.65; H, 6.18; N, 13.22. Found: C, 39.80; H, 5.91; N, 13.50.

***N*-Cyano-*N*-ethylpiperidinium fluoroborate** was prepared by the same procedure as that of *N*-cyano-*N,N,N*-tri-*n*-butylammonium fluoroborate (91% yield): mp 108–110°; ir (Nujol mull) 2263 (weak, CN) and 1000–1100 cm^{-1}; nmr (acetone-d_6) δ 1.63 (t, CH_2, 3 H), 1.33–2.60 (br, CH_2, 6 H), and 3.74–4.73 (br, CH_2N^+, 6 H).

Anal. Calcd for $C_8H_{15}N_2BF_4$ (226.02): C, 42.51; H, 6.69; N, 11.65. Found: C, 42.45; H, 6.76; N, 12.10.

***N*-Cyano-*N*-*n*-propylpiperidinium fluoroborate** was prepared by the same procedure as that of *N*-cyano-*N,N,N*-tri-*n*-butylammonium fluoroborate (86% yield): mp 83–85°; ir (Nujol mull) 2260 (weak, CN) and 1000–1100 cm^{-1}; nmr (acetone-d_6) δ 1.11 (5, CH_3, 3 H), 1.40–2.50 (br, CH_2, 8 H), and 3.74–4.4 (m, CH_2N^+, 6 H).

Anal. Calcd for $C_9H_{17}N_2BF_4$ (240.05): C, 45.03; H, 7.14; N, 11.76. Found: C, 44.85; H, 7.40; N, 11.45.

***N*-Cyano-*N*-*n*-butylpiperidinium fluoroborate** was prepared by the same procedure as that of *N*-cyano-*N,N,N*-tri-*n*-butylammonium fluoroborate (85% yield): mp 68–69°; ir (Nujol mull) 2270 (weak, CN) and 1000–1100 cm^{-1}; nmr (acetone-d_6) δ 1.00 (t, CH_3, 3 H), 1.10–2.50 (m, CH_2, 10 H), and 3.74–4.73 (br, CH_2N^+, 6 H).

Anal. Calcd for $C_{10}H_{19}N_2BF_4$ (253.29): C, 47.27; H, 7.54; N, 11.03. Found: C, 47.20; H, 7.40; N, 11.10.

Reaction of *N*-Methylaniline with *N*-Cyanoammonium Fluoroborates. 1. *N*-Cyano-*N,N,N*-triethylammonium Fluoroborate. To a solution of 2.14 g (0.01 mol) of *N*-cyano-*N,N,N*-triethylammonium fluoroborate in 10 ml of acetonitrile was added 1.07 g (0.01 mol) of *N*-methylaniline. The solution was allowed to stand for 1 day. It was refluxed for 5 min, the solvent was removed by azeotropic distillation with isopropyl ether (bp 63.5–68°), and the residue was extracted with ether (4.50 ml) to separate the ammonium salt. The ether layer was washed with water (15 ml), dried (Na_2SO_4), and evaporated on a rotary evaporator at room temperature to give a pale yellow oil. The oil was dissolved in 200 ml of ether and washed with 30 ml of 1 *N* HCl solution to remove unreacted *N*-methylaniline. The ether layer was washed with a small amount of water, dried (Na_2SO_4), and distilled to give 0.89 g (88%) of diethylcyanamide. The distillation residue contained *N*-methylcyananilide as the major component which was further purified by column chromatography on deactivated silica gel using 10:1 cyclohexane–ethyl acetate as solvent. *N*-Methylcyananilide was identified by comparison of nmr spectra with those of an authentic sample prepared by the reaction of cyanogen bromide with *N*,*N*-dimethylaniline.[1] The nmr signal of an impurity appeared at δ 0.8–1.9 ppm in CCl_4. The ether-insoluble products were dissolved in 30 ml of water and treated with 1.50 g of sodium hydroxide under 200 ml of ether. The ether-extracted portion was distilled to give 1.10 g (82%) of *N*-methyl-*N*-ethylaniline. Diethylcyanamide was analyzed as follows: ir (thin film) 2213 cm^{-1} (strong, CN); nmr (CCl_3) δ 1.25 (t, CH_3, 6 H) and 3.20 (q, CH_2, 4 H); mass spectrum *m/e* (rel abundance) 98 (M^+, 34), 87 (6), 85 (42), 84 (6), 83 (6), 70 (11), 69 (12), 58 (25), 56 (6), 55 (100), 53 (6), 49 (9), 48 (10), 47 (22), 44 (9), 43 (98), 42 (20), 41 (6).

Anal. Calcd for $C_5H_{10}N_2$ (98.15): C, 61.18; H, 10.27; N, 28.55. Found: C, 61.30; H, 10.42; N, 28.02.

2. *N*-Cyano-*N*,*N*,*N*-tri-*n*-butylammonium Fluoroborate. Three grams (0.01 mol) of *N*-cyano-*N*,*N*,*N*-tri-*n*-butylammonium fluoroborate and 1.07 g (0.01 mol) of *N*-methylaniline were allowed to react in 10 ml of acetonitrile as in 1 to give 1.50 g of ether-soluble product mixture which was shown to contain di-*n*-butylcyanamide as the major component and a minor component which had a singlet at δ 3.24 ppm in CCl_4. The crude product was purified by column chromatography on silica gel using 10:1 cyclohexane–ethyl acetate as solvent to give 0.87 g (56.5%) of di-*n*-butylcyamide as the second fractions. The first fractions contained most of the *N*-methylcyananilide and weighed about 0.05 g. The ether-insoluble portion gave, after base treatment, 1.40 g (83%) of *N*-methyl-*N*-*n*-butylaniline, which was purified by column chromatography on silica gel using 10:1 cyclohexane–ethyl acetate as solvent. The nmr spectrum (CCl_4) had signals at δ 0.91 (t, CH_3, 3 H), 1.07–1.80 (br, CH_2, 4 H), 2.85 (s, CH_3, 3 H), 3.17 (t, CH_2, 2 H), 6.43–6.63 (m, phenyl ring, 3 H), 6.91–7.23 (m, phenyl ring, 2 H). Di-*n*-butylcyanamide was characterized as follows: bp 70–71° (0.5 mm); ir (thin film) 2205 cm^{-1} (strong, CN); nmr (CCl_4) δ 0.97 (t, CH_3, 6 H), 1.20–1.90 (m, CH_2, 8 H), 2.97 (t, CH_2, 4 H); mass spectrum *m/e* (rel abundance) 154 (M^+, 23), 139 (7), 125 (9), 112 (10), 111 (44), 98 (9), 97 (7), 86 (8), 83 (7), 70 (11), 69 (100), 57 (44), 55 (19), 43 (13), 42 (10), 41 (41), 39 (8).

Reaction of *N*-Methylcyclohexylamine with *N*-Cyanoammonium Fluoroborates. 1. *N*-Cyano-*N*,*N*,*N*-triethylammonium Fluoroborate. To a solution of 2.14 g (0.01 mol) of *N*-cyano-*N*,*N*,*N*-triethylammonium fluoroborate in 10 ml of acetonitrile was added 1.13 g (0.01 mol) of *N*-methylcyclohexylamine. The reaction mixture was allowed to stand at room temperature for several hours. The solvent was removed on a rotary evaporator at room temperature, and the residue was extracted with ether (3 × 100 ml), which was washed with 15 ml of water, dried (Na_2SO_4), and evaporated at room temperature to give 1.13 g (85%) of crude *N*-methylcyclohexylcyanamide. The nmr spectrum of this product in CCl_4 showed small peaks at around δ 3 ppm, but the impurity was not characterized. Distillation, bp 72° (0.32 mm), of this product gave an analytically pure sample which was characterized as follows: ir (thin film) 2200 cm^{-1} (strong, CN); nmr (CCl_4) δ 1.75 (br, CH_2, 10 H), 2.83 (br, CH, 1 H), 2.85 (s, CH_3, 3 H); mass spectrum *m/e* (rel abundance) 138 (M^+, 55), 137 (11), 123 (8), 121 (5), 111 (5), 110 (11), 109 (15), 105 (8), 98 (8), 97 (8), 96 (17), 95 (88), 84 (11), 83 (93), 82 (26), 81 (15), 77 (6), 71 (6), 70 (15), 69 (26), 68 (13), 76 (38), 58 (6), 57 (98), 56 (15), 55 (100), 54 (22), 53 (18), 44 (11), 43 (68), 41 (87), 40 (6), 39 (32).

Anal. Calcd for $C_8H_{14}N_2$ (138.21): C, 69.52; H, 10.21; N, 20.27. Found: C, 69.54; H, 10.00; N, 20.10.

2. *N*-Cyano-*N*,*N*,*N*-tri-*n*-butylammonium Fluoroborate. Three grams (0.01 mol) of *N*-cyano-*N*,*N*,*N*-tri-*n*-butylammonium fluoroborate and 1.13 g (0.01 mol) of *N*-methylcyclohexylamine were allowed to react as in 1 in 10 ml of acetonitrile to give 1.40 g (99%) of crude *N*-methylcyclohexylcyanamide, which was distilled in a Hickman still (80°) to give an analytically pure sample of *N*-methylcyclohexylcyanamide.

3. *N*-Cyano-*N*-*n*-propylpiperidinium Fluoroborate. Three grams (0.0125 mol) of *N*-cyano-*N*-propylpiperidinium fluoroborate and 1.50 g (0.13 mol) of *N*-methylcyclohexylamine were allowed to react as in 1 in 10 ml of acetonitrile to give 1.67 g (97%) of crude *N*-methylcyclohexylcyanamide, which gave, after distillation in a Hickman still (80°), a clear oil whose ir and nmr spectra were identical with those obtained previously.

Reaction of Isobutylamine with *N*-Cyanoammonium Fluoroborates. 1. *N*-Cyano-*N*,*N*,*N*-triethylammonium Fluoroborate. To a solution of 2.14 g (0.01 mol) of *N*-cyano-*N*,*N*,*N*-triethylammonium fluoroborate in 10 ml of acetonitrile was added 0.75 (0.01 mol) of isobutylamine. The solution was allowed to stand at room temperature for several hours, and the solvent was removed on a rotary evaporator at room temperature. The residue was extracted with ether (3 × 100 ml) and the ether layer was washed with 15 ml of water, dried (Na_2SO_4), and distilled to give 0.8 g (81.5%) of crude isobutylcyanamide as a residue whose nmr spectrum in CCl_4 did not show any peaks at around δ 3 ppm. Distillation at 73° (0.35 mm) gave a clear oil of isobutylcyanamide which was characterized as follows: ir (thin film) 3166 (strong, NH) and 2218 cm^{-1} (strong, CN); nmr ($CDCl_3$) δ 0.92 (d, CH_3, 6 H), 1.83 (m, CH, 1 H), 2.83 (d, CH_2, 2 H), and 4.68 (br, NH, 1 H). This cyanamide was trimerized on standing to a solid, which was characterized as follows: mp 86–90°; ir (thin film) 3346 (strong, NH), 1613, and 1492 cm^{-1}; mass spectrum *m/e* (rel abundance) 294 (M^+, 3), 279 (7), 237 (6), 223 (6), 182 (12), 181 (9), 167 (12), 140 (22), 127 (20), 126 (20), 99 (5), 98 (40), 97 (6), 84 (7), 83 (53), 70 (14), 69 (16), 58 (6), 57 (15), 56 (13), 55 (100), 53 (5), 44 (4), 43 (14), 42 (14), 41 (12).

Anal. Calcd for $C_{15}H_{30}N_6$ (294.45): C, 61.18; H, 10.27; N, 28.54. Found: C, 61.30; H, 10.10; N, 28.60.

2. *N*-Cyano-*N*,*N*,*N*-tri-*n*-butylammonium Fluoroborate. To a solution of 1.50 g (0.005 mol) of *N*-cyano-*N*,*N*,*N*-tri-*n*-butylammonium fluoroborate in 10 ml of acetonitrile, 0.38 (0.005 mol) of isobutylamine was added. The solution was allowed to react and worked up as in 1 to give 0.47 g (99%) of isobutylcyanamide, which was short-path distilled [82° (0.45 mm)] to give a clear oil whole ir and nmr spectra were identical with those obtained in 1.

Reaction of Thiophenol with *N*-Cyanoammonium Fluoroborates. 1. *N*-Cyano-*N*,*N*,*N*-triethylammonium Fluoroborate. To a solution of 0.88 g (0.041 mol) of *N*-cyano-*N*,*N*,*N*-triethylammonium fluoroborate in 10 ml of acetonitrile was added 0.49 g (0.0045 mol) of thiophenol. The mixture was allowed to stand at room temperature for several hours and refluxed briefly, followed by removal of the solvent by azeotropic distillation with isopropyl ether (bp 63.5–68°). The residue was extracted with ether (3 × 100 ml), and the ether portion was evaporated on a rotary evaporator without heating to give a pale yellow oil whose nmr spectrum showed only phenyl groups. The oil was dissolved in 300 ml of ether, and the ether solution was washed with 10 ml of 2 *N* NaOH solution and 15 ml of water, dried (Na_2SO_4), and distilled in a short-path distillation column to give 0.45 g (67%) of phenyl thiocyanate. The residue was a small amount of phenyl disulfide, which was identified by comparison with an authentic sample by ir and nmr spectroscopy. Phenyl thiocyanate was characterized as follows: ir (thin film) 2156 cm^{-1} (strong, SCN); nmr ($CDCl_3$) δ 7.37 (m, phenyl ring); mass spectrum showed molecular ion at *m/e* 135.

Anal. Calcd for C_7H_5NS (135.18): C, 62.19; H, 3.73; N, 10.36. Found: C, 62.15; H, 3.82; N, 10.48.

2. *N*-Cyano-*N*,*N*,*N*-tri-*n*-butylammonium Fluoroborate. A solution of 3.00 g (0.01 mol) of *N*-cyano-*N*,*N*,*N*-tri-*n*-butylammonium fluoroborate in 20 ml of acetonitrile and 2.30 (0.021 mol) of thiophenol were allowed to react and worked up as in 1 to give 2.0 g of ether-soluble product mixture. Distillation [130° (0.20 mm)] in a short-path distillation column gave 0.15 g (11%) of crude phenyl thiocyanate and 1.80 g (82.5%) of phenyl disulfide as residue. Phenyl disulfide was recrystalized from ethanol and characterized as follows: mp 59–59.5° (lit.[31] mp 61–62°); ir (Nujol mull) 1517, 1432, 1375, 1069, 1022, 896, 834, 737, and 685 cm^{-1}; nmr ($CDCl_3$) δ 7.25 (m, phenyl ring); mass spectrum showed molecular ion at *m/e* 218.

Anal. Calcd for $C_{12}H_{10}S_2$ (218.33): C, 66.01; H, 4.62. Found: C, 65.75; H, 4.77.

3. *N*-Cyano-*N*-*n*-propylpiperidinium Fluoroborate. A solution of 3.00 g (0.0125 mol) of *N*-cyano-*N*-*n*-propylpiperidinium fluoroborate in 20 ml of acetonitrile and 1.65 g (0.015 mol) of thiophenol were allowed to react and worked up as in 1 to give 1.25 g of crude phenyl thiocyanate, bp 116° (0.15 mm), and 0.61 g of phenyl disulfide. (The minimum yield of the formed thiocyanate was calculated to be 92%.)

Reaction of Sodium Thiophenolate with *N*-Cyanoammonium Fluoroborates. 1. *N*-Cyano-*N*,*N*,*N*-triethylammonium Fluoroborate. A solution of 1.58 g (0.0074 mol) of *N*-cyano-*N*,*N*,*N*-triethylammonium fluoroborate in 20 ml of acetonitrile was added to 1.78 g (0.0135 mol) of sodium thiophenolate (prepared from sodium and thiophenol in ethanol). The reaction mixture was allowed to stand at room temperature for several hours. The solvent was removed on a rotary evaporator and the residue was extracted with ether (3 × 100 ml). Distillation gave 1.32 g (89.5%) of phenyl disulfide as residue.

2. ***N*-Cyano-*N*,*N*,*N*-tri-*n*-butylammonium Fluoroborate.** A solution of 3.00 g (0.01 mol) in 10 ml of acetonitrile was added to 2.80 g (0.021 mol) of sodium thiophenolate. The solution was allowed to react and worked up as in 1 to give 2.09 g (95%) of phenyl disulfide, which gave, after recrystalization from ethanol, identical ir and nmr spectra with those obtained in the previous experiment.

Reaction of Triphenylphosphine with *N*-Cyanoammonium Fluoroborates. 1. *N*-Cyano-*N*,*N*,*N*-triethylammonium Fluoroborate. To a solution of 2.14 g (0.01 mol) of *N*-cyano-*N*,*N*,*N*-triethylammonium fluoroborate in 20 ml of acetonitrile, 1.31 g (0.005 mol) of triphenylphosphine was added. The reaction mixture was allowed to stand at room temperature for several hours. The precipitated colorless crystals were collected, washed with ether, and dried under vacuum to give 0.76 g (51%) of a compound eventually identified as difluorotriphenylphosphorane. The mother liquor was evaporated on a rotary evaporator at room temperature, and the residue was extracted with petroleum ether (2 × 100 ml) to give, by distillation of the solvent, 0.07 g of diethylcyanamide. The unextracted material could not be purified by continuous extraction with ether. It was treated with decolorizing carbon in 100 ml of ethyl acetate and the addition of ether precipitated 1.40 g of very unstable, colorless crystals which were dried under vacuum for several days. The crystals gave very similar ir and nmr spectra to those of the adduct of triethylamine and boron trifluoride formed in ether, but satisfactory elemental analysis could not be obtained owing to the instability. Difluorotriphenylphosphorane was characterized as follows: mp 147–149° (lit.[28] mp 158–162°); nmr (acetone-d_6) δ 7.50, 7.90, and 8.10 (m's in 2:1:1 ratio); ^{19}F nmr (acetone, internal $CFCl_3$) ϕ 38.72 (doublet, J_{P-F} = 665.2 Hz (lit.[24] ϕ 40.4, J_{P-F} = 660 Hz in $CHCl_3$); mass spectrum *m/e* (rel abundance) 300 (M^+, 0.4), 281 (3), 279 (3), 223 (21), 205 (11), 204 (100), 203 (22), 202 (4), 183 (5), 154 (17), 152 (5), 127 (23), 77 (24), 51 (12).

Anal. Calcd for $C_{18}H_{15}PF_2$ (300.275): C, 71.99; H, 5.04. Found: C, 72.10; H, 5.06.

2. ***N*-Cyano-*N*,*N*,*N*-tri-*n*-butylammonium Fluoroborate.** To a solution of 3.00 g (0.01 mol) of *N*-cyano-*N*,*N*,*N*-tri-*n*-butylammonium fluoroborate in 20 ml of acetonitrile was added 1.31 g (0.005 mol) of triphenylphosphine. The solution was allowed to react and worked up as in 1 to give 1.46 g (93%) of difluorotriphenylphosphorane.

Reaction of Water with *N*-Cyanoammonium Fluoroborates. 1. *N*-Cyano-*N*,*N*,*N*-triethylammonium Fluoroborate. To a solution of 2.14 g (0.01 mol) of *N*-cyano-*N*,*N*,*N*-triethylammonium fluoroborate in 20 ml of acetonitrile was added 0.20 ml of water. The reaction mixture was allowed to stand at room temperature for 3 days. It was refluxed briefly and the solvent was removed by distillation. The distillate showed a quartet at δ 3.47 ppm (in acetonitrile). The distillation residue was extracted with ether (3 × 100 ml) and the ether layer was evaporated on a rotary evaporator at room temperature to give 0.12 g (11%) of crude diethylcyanamide, which was distilled in a Hickman still as a clear oil whose nmr and ir spectra were identical with those obtained earlier. The ether-insoluble product mixture was dissolved in 100 ml of acetonitrile and filtered to give the undissolved colorless crystals of ammonium fluoroborate weighing 0.19 g (15%). The acetonitrile solution was evaporated to give crude triethylammonium fluoroborate weighing 1.50 g (84%), whose ir and nmr spectra were identical with those of an authentic sample. Elemental analysis of ammonium fluoroborate was as follows.

Anal. Calcd for NH_4BF_4 (129.07): H, 3.85; N, 13.40. Found: H, 4.04; N, 13.15.

2. ***N*-Cyano-*N*,*N*,*N*-tri-*n*-butylammonium Fluoroborate.** To a solution of 1.50 g (0.005 mol) of *N*-cyano-*N*,*N*,*N*-tri-*n*-butylammonium fluoroborate in 20 ml of acetonitrile, 0.20 ml of water was added and the solution was allowed to react and worked up in 1; 0.14 g (9.1%) of di-*n*-butylcyanamide, 0.09 g (14%) of ammonium fluoroborate, and 1.14 g (83.5%) of tri-*n*-butylammonium fluoroborate were obtained. Di-*n*-butylcyanamide was purified by column chromatography on silica gel using 1:1 hexane–ethyl acetate as solvent. The three products gave ir and nmr spectra identical with those of authentic samples obtained earlier.

Reaction of Dimethylformamide with *N*-Cyanoammonium Fluoroborates. 1. *N*-Cyano-*N*,*N*,*N*-triethylammonium Fluoroborate. To a solution of 2.14 g (0.01 mol) of *N*-cyano-*N*,*N*,*N*-triethylammonium fluoroborate in 20 ml of acetonitrile was added 0.75 g (0.01 mol) of dimethylformamide. The solution was allowed to stand for 2 days at room temperature and refluxed for 2 hr, followed by the addition of 0.20 ml (0.011 mol) of water. The solution was refluxed for an additional 2 hr and the solvent was removed by azeotropic distillation with isopropyl ether (bp 63.5–68°). The distillation residue was extracted with ether (3 × 100 ml), and the ether portion was washed with 15 ml of water, dried (Na_2SO_4), and evaporated on a rotary evaporator at room temperature to give 0.79 g (80.6%) of diethylcyanamide, which was short-path distilled to give a clear oil whose ir and nmr spectra were identical with those obtained earlier. The ether-insoluble product was 1.10 g (82.5%) of crude dimethylammonium fluoroborate as determined by nmr spectroscopy.

2. ***N*-Cyano-*N*,*N*,*N*-tri-*n*-butylammonium Fluoroborate.** To a solution of 1.50 g (0.005 mol) of *N*-cyano-*N*,*N*,*N*-tri-*n*-butylammonium fluoroborate in 20 ml of acetonitrile was added 0.37 g (0.005 mol) of dimethylformamide. The solution was allowed to react and worked up as in 1 to give 0.62 g (82%) of di-*n*-butylcyanamide, which was distilled in a Hickman still to give a clear oil whose ir and nmr spectra were identical with those obtained earlier.

3. ***N*-Cyano-*N*-*n*-propylpiperidinium Fluoroborate.** To a solution of 3.0 g (0.0125 mol) of *N*-cyano-*N*-*n*-propylpiperidinium fluoroborate in 20 ml of acetonitrile, 0.95 g (0.013 mol) of dimethylformamide was added. The solution was allowed to react as in 1. The reaction mixture was distilled, and the distillate was examined by nmr spectroscopy to show two different triplets at about δ 4.08 and 3.40 ppm in acetonitrile. (The former triplet was assigned to the methylene protons of the expected *n*-propyl formate.) The distillation residue was extracted with methylene chloride (3 × 100 ml) and distilled to give 0.41 g (30%) of piperidine cyanamide and 1.10 g (52%) of 5-hydroxypentyl-*n*-propylcyanamide. Piperidine cyanamide contained a small amount of dimethylformamide, which was removed by washing with water. The methylene chloride insoluble portion was crystalized and washed with ether in a continuous-extraction column to give 1.61 g (97%) of dimethylammonium fluoroborate. Piperidine cyanamide was characterized as follows: bp 41° (0.65 mm); ir (thin film) 2203 cm^{-1} (strong, CN); nmr ($CDCl_3$) δ 1.60 (br, CH_2, 6 H) and 3.17 (br, CH_2N, 4 H); mass spectrum *m/e* (rel abundance) 110 (M^+, 100), 111 (8), 109 (78), 95 (6), 83 (5), 82 (10), 81 (5), 69 (64), 67 (10), 58 (12), 57 (28), 56 (13), 55 (44), 54 (13), 53 (10), 44 (22), 43 (40), 42 (99), 41 (39), 40 (5), 39 (15).

Anal. Calcd for $C_6H_{10}N_2$ (110.16): C, 65.41; H, 9.15; N, 25.44. Found: C, 65.45; H, 9.25; N, 25.00.

5-Hydroxypentyl-*n*-propylcyanamide was characterized as follows: bp 140° (0.65 mm); ir (thin film) 2203 cm^{-1} (strong, CN); nmr ($CDCl_3$) δ 0.97 (t, CH_3, 3 H), 1.40–1.90 (m, CH_2, 8 H) 2.90–3.40 (m, CH_4, 4 H), and 3.60 (t, CH_2, 2 H); mass spectrum *m/e* (rel abundance) 170 (M^+, 4), 155 (15), 142 (4), 141 (10), 128 (19), 127 (8), 126 (5), 125 (10), 123 (6), 114 (16), 113 (6), 112 (7), 111 (10), 110 (4), 105 (8), 100 (11), 99 (9), 98 (22), 97 (35), 88 (6), 96 (8), 88 (5), 86 (6), 85 (51), 84 (7), 83 (13), 82 (7), 81 (43), 80 (15), 79 (8), 77 (17), 75 (39), 72 (22), 71 (5), 70 (25), 69 (48), 58 (8), 57 (21), 56 (14), 55 (100), 54 (16), 53 (11), 51 (7), 45 (6), 44 (18), 43 (68), 42 (22), 41 (85), 39 (28).

Anal. Calcd for $C_9H_{18}N_2O$ (170.25): C, 63.49; H, 10.65; N, 16.46. Found: C, 63.60; H, 10.40; N, 16.25.

Registry No.—1 (R = Et), 30684-36-7; 1 (R = Bu), 30684-37-8; 2 (R = Me), 30759-79-6; 2 (R = Et), 51108-21-5; 2 (R = Pr), 51108-23-7; 2 (R = Bu), 30759-80-9; cyanogen bromide, 506-68-3; triethylamine, 121-44-8; triethyloxomium fluoroborate, 368-39-8; tri-*n*-butylamine, 102-82-9; *N*-methylpiperidine, 626-67-5; *N*-ethylpiperidine, 766-09-6; *N*-propylpiperidine, 5470-02-0; *N*-*n*-butylpiperidine, 4945-48-6; *N*-methylaniline, 100-61-8; diethylcyanamide, 617-83-4; *N*-methyl-*N*-*n*-butylaniline, 3416-49-7; *N*-methylcyclohexylamine, 100-60-7; *N*-methylcyclohexylcyanamide, 49677-01-2; isobutylamine, 78-81-9; isobutylcyanamide, 13519-17-0; isobutylcyanamide trimer, 51056-91-8; thiophenol, 108-98-5; phenyl thiocyanate, 5285-87-0; phenyl disulfide, 882-33-7; sodium thiophenolate, 930-69-8; triphenylphosphine, 603-35-0; difluorotriphenylphosphorane, 845-64-7; water, 7732-18-5; ammonium fluoroborate, 13826-83-0; dimethylformamide, 68-12-2; piperidine cyanamide, 1530-87-6; 5-hydroxypentyl-*n*-propylcyanamide, 51056-92-9.

References and Notes

(1) Taken in part from the Ph.D. Thesis of M. Kim, Kansas State University, 1973. Financial support from the National Science Foundation Grant No. GP 15334 and a grant to the Department of Chemistry for the purchase of XL-100-15 and T-60 nmr spectrometers is gratefully acknowledged.
(2) J. von Braun, *Chem. Ber.*, **33**, 1438 (1900).
(3) R. Scholl and W. Noerr, *Chem. Ber.*, **33**, 1550 (1900).
(4) H. A. Hageman, *Org. React.*, **7**, 198 (1953).
(5) B. S. Thyagarajan, *Intra-Sci. Chem. Rep.*, **2**, 1 (1968).
(6) J. V. Paukstelis and M. Kim, *Tetrahedron Lett.*, 4731 (1970).
(7) G. Fodor and S. Abidi, Abstracts, 160th National Meeting of the American Chemical Society, Chicago, Ill., Sept 1970, ORGN 117; G. Fodor and Abidi, *Tetrahedron Lett.*, 1369 (1971).
(8) D. W. A. Sharp, *Advan. Fluorine Chem.*, **1**, 68 (1960).
(9) H. Meerwein, *Org. Syn.*, **46**, 113 (1966); K. Hafner and H. Pelster, *Angew. Chem.*, **73**, 342 (1961).
(10) W. O. Freitag and E. R. Nixon, *J. Chem. Phys.*, **24**, 109 (1956).
(11) R. E. Kiston and N. E. Griffth, *Anal. Chem.*, **24**, 334 (1952).
(12) J. D. Jesson and H. W. Thompson, *Spectrochim. Acta*, **13**, 217 (1958).
(13) H. W. Thompson and G. Still, *Trans. Faraday Soc.*, **52**, 451 (1956).
(14) G. L. Cote and H. W. Thompson, *Proc. Roy. Soc., Ser. A*, **210**, 217 (1958).
(15) D. W. A. Sharp and N. Sheppard, *J. Chem. Soc.*, 674 (1957).
(16) J. von Braun, *Chem. Ber.*, **42**, 2035 (1905).
(17) E. Erlenmyer, *Justus Liebigs Ann. Chem.*, **146**, 258 (1868).
(18) A. Schoeberl, "Methoden der Organischen Chemie," Vol. 9, Georg Thieme Verlag, Stuttgart, 1955, p 69.
(19) W. O. Foye, A. M. Hebb, and J. Mickles, *J. Pharm. Sci.*, **56**, 292 (1967).
(20) (a) O. C. Billerter, *Chem. Ber.*, **7**, 1753 (1874); (b) S. Gabriel, *ibid.*, **10**, 184 (1877); (c) S. Gabriel and A. Deutsch, *ibid.*, **13**, 386 (1880).
(21) L. A. Spurlock, R. K. Poter, and W. G. Cox, *J. Org. Chem.*, **37**, 1162 (1972).
(22) J. von Braun and P. Engelbertz, *Chem. Ber.*, **56**, 1573 (1923).
(23) R. G. R. Bacon and J. Koechling, *J. Chem. Soc., Suppl. 1*, 5594 (1964).
(24) G. S. Reddy and R. Schmutzler, *Z. Naturforsch. B*, **25**, 1199 (1970).
(25) L. Honer and H. Oedinger, *Justus Liebigs Ann. Chem.*, **626**, 26 (1959).
(26) K. Issleib and W. Seidel, *Z. Anorg. Allg. Chem.*, 288 (1956).
(27) (a) W. C. Smith, *J. Amer. Chem. Soc.*, **82**, 6176 (1960); (b) W. C. Frith, S. F. M. Garber, and U. P. Wystrach, *Inorg. Chem.*, **4**, 765 (1965).
(28) J. von Braun, *Chem. Ber.*, **44**, 1252 (1911).
(29) J. V. Paukstelis and M. Kim, *Syn. Commun.*, **3**, 333 (1973).
(30) All melting points were taken on a Nalge microscopic hot stage and are uncorrected except those used for comparison. Infrared spectra were obtained on a Perkin-Elmer 137 double-beam recording spectrometer. Nmr spectra were determined on Varian T-60, A-60, or XL-100 recording spectrometers. Mass spectra were obtained using an AEI MS-9 recording spectrometer. Microanalysis were performed by the Chemistry Department, Kansas State University, Manhattan, Kan. Temperatures for short-path distillations were pot temperatures.

N-Alkoxycarbonyl-*N,N,N*-trialkylammonium Fluoroborates. Formation of Carbonic Anhydrides in Peptide Synthesis

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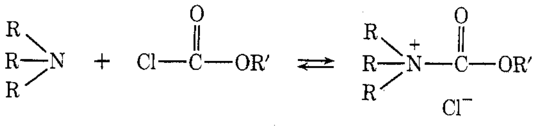
A variety of *N*-alkoxycarbonyl-*N,N,N*-trialkylammonium fluoroborates have been synthesized from tertiary amines and alkyl chloroformates. The salts are stable and can be used in the mixed anhydride method of peptide synthesis. The yields of peptides are similar to those observed previously but the amount of racemization is apparently reduced as determined by the Anderson test. The salts also react readily with primary and secondary amines to give urethanes.

The occurrence of simple *N*-alkoxycarbonyl-*N,N,N*-trialkylammonium salts has been postulated many times[3-8] but stable salts have been isolated only rarely.[9-11] The highly stabilized derivatives of 4-(*N,N*-dimethylamino)pyridine[10] and *N*-methylimidazole[11] may not even be in a strict sense *N*-alkoxycarbonylammonium salts. Thus there remains only the report of simple *N*-alkoxycarbonylammonium salt preparation by reaction of urethanes with methyl fluorosulfonate[9] followed by rearrangement.

Our interest in preparing the *N*-alkoxycarbonylammonium salts required preparation of wide variety of structures and high yields for use in the mixed anhydride method of peptide synthesis. We felt that if such salts can be made and used then the mixed anhydride method would be completely free of excess bases (in the formation of the mixed anhydride) that might lead to racemization.[12] Currently the *N*-alkoxycarbonylammonium salts are prepared by mixing tertiary amino and alkyl chloroformates.[12-16] Chloride ion is a fairly good nucleophile; thus the reaction can never be completely free of base because the reaction is always somewhat reversible. If the reagents can be readily formed then it also may be useful in the formation of N, O, and S protecting groups.

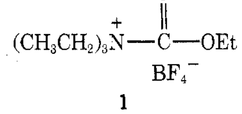


$$R_3N + Cl{-}\overset{O}{\overset{\|}{C}}{-}OR' \rightleftharpoons R_3\overset{+}{N}{-}\overset{O}{\overset{\|}{C}}{-}OR'\ \ Cl^-$$

To eliminate the problem of reversibility we chose to exchange the chloride for fluoroborate. The fluoroborate ion is less nucleophilic[17] and in our experience yields stable, nonhydroscopic salts.[18,19]

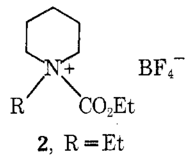
The adducts of tertiary amines and alkyl chloroformates were obtained by mixing the two reactants in ether at −78°. The addition compounds were generally observed as colorless crystals and appeared stable at room temperature under ether. Detailed examination by nmr spectroscopy and elemental analysis indicated that the substances were usually a mixture.

The anion exchange reaction was facile when the HF/BF_3 mixture was added to the adducts of tertiary amines and alkyl chloroformates at −78°. Stirring until room temperature was reached gave colorless crystals of *N*-alkyloxycarbonylammonium fluoroborates (**1–12**) in 89–99% yield. Most salts showed sharp melting points and varied in their stability. The pyridine derivatives were very unstable, and among those derived from aliphatic amines the stability increased as the alkyl groups became bulkier. The derivatives of *N,N*-dimethylcyclohexylamine and isopropyl, *sec*-butyl, or isobutyl chloroformate were the most stable *N*-alkyloxycarbonylammonium salts, allowing easy



$$(CH_3CH_2)_3\overset{+}{N}{-}\overset{O}{\overset{\|}{C}}{-}OEt\ \ BF_4^-$$

1



2, R = Et
3, R = *n*-Pr
4, R = *n*-Bu