vpc (above conditions) and was identified as 4-ethyl-3,4-dimethyl-1(4H)-naphthalenone (**22**). The spectroscopic properties of naphthalenone **22** are presented in Table I.

Irradiation of Naphthalenone 20 in Trifluoroethanol.—A solution of 50 mg of naphthalenone **20** in 5 ml of trifluoroethanol was irradiated through a uranium glass filter (short wavelength cutoff at *ca.* 360 mμ). Vapor phase chromatography (5 ft × 0.25 in. DEGS column, 180°, 100 ml/min of helium) of the photolysis solution after 15-min irradiation showed that the photolysate had components with the following retention times: 4.1 (naphthalenone **20**, 51%), 5.4 (11%), and 15.3 min (38%). Examination of the photolysate by vpc after irradiation for 1 hr indicated the presence of a single component with a retention time of 15.3 min. The photoproduct was purified by vpc and was identified by its infrared spectrum and retention time as naphthalenone **22**.

Similarly, irradiation of a solution of 110 mg of naphthalenone **20** in 11 ml of trifluoroethanol through a Pyrex filter for 2 hr proceeded with complete conversion and provided a 90% yield of naphthalenone **22**.

Registry No.—**7**, 23740-88-7; **9**, 23740-89-8; **13**, 23740-90-1; **14**, 2981-97-7; **20**, 23740-92-3; **22**, 23740-93-4; **24**, 23740-94-5.

Titanium Tetrachloride Promoted Condensations of Amines with Carboxamides and Similar Species

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Titanium tetrachloride–amine complexes aminate nonhindered carboxamides, β-dicarbonyl compounds, and vinylogous carboxylic acids. Amidinium and vinylogous amidinium salts are formed. In the presence of excess amine, certain amidinium ions are converted into their conjugate bases, enediamines.

Recently we have reported the titanium tetrachloride promoted amination of carbonyl compounds to give enamines,[1a] imines,[1b] and carboxamides.[2] We report here the further amination of carboxamides, which give amidinium salts,[3] and the amination of β diketones and tropolone, which can be regarded as vinylogous carboxylic acids and which give vinylogous amidinium salts as products. This reaction provides a very convenient route to symmetrically substituted amidinium salts and their derivatives.

Results and Discussion

Amination reactions were carried out on a number of representative carboxamides, acetylacetone, and tropolone, the results of which are collected in Table I. Dimethylamine was generally used as the amine component of the reagent to simplify nmr spectral analysis of the products, but other amines, *e.g.*, N,N′-dimethylethylenediamine and 1,2-dimethylhydrazine, proved equally effective. The reaction follows the stoichiometry of eq 1. The reactions were run in a solvent;

$$2R'CONR_2 + 4R_2NH + TiCl_4 \longrightarrow 2R'C(NR_2)_2{}^+Cl^- + 2R_2NH_2Cl + TiO_2 \quad (1)$$

THF or excess dimethylamine (under pressure) proved particularly convenient.

The amination of carboxamides is a significantly more difficult reaction to accomplish than the amination of ketones or carboxylic acids. While virtually any ketone can be converted into its corresponding enamine and any carboxylic acid into its amide by the complexes formed in the interaction of $TiCl_4$ with primary or secondary amines,[4] only nonsterically hindered amides undergo further amination. Thus the N,N-dimethylamides of formic, acetic, and propionic acids react (with decreasing rapidity) with the $TiCl_4$–$(CH_3)_2NH$ reagent to give good yields of tetramethylamidinium salts, but with the more highly substituted isobutyric amide the reaction stops at an intermediate stage, and N,N-dimethylpivalamide is inert. On the other hand, N,N-dimethyldichloracetamide and N,N-dimethylphenylacetamide react fairly readily, showing that there is a delicate balance among factors which determine the reactivity of these compounds.

Tropolone is about as reactive as carboxylic acids toward amination, but acetylacetone reacts very rapidly to give a high yield of vinylogous amidinium salt product.

The product isolated from each reaction is apparently dependent on the acidity of the initially formed amidinium ion. In general, compounds without a hydrogen atom α to the carboxyl group, alkyl derivatives of acetic acid, acetylacetone, and tropolone yield the amidinium (or vinylogous amidinium) salt, whereas electronegatively substituted acetic acids yield enediamines. With dimethylacetamide itself, the reaction can be run so as to yield either tetramethylacetamidinium chloride (**1**) or its conjugate base, vinylidenebis(dimethylamine) (**2**).[5] Evidently, the α-hydrogen-bearing amidinium ions are carbon acids of the same order of acid strength as dimethylammonium ion, and in the presence of excess dimethylamine (as these reactions are normally run) the stronger acids are converted into their conjugate bases.

However, N,N,N′,N′-tetramethylpropanamidinium chloride (**3**) is not so converted into its conjugate base, which implies that it must be a considerably weaker acid than **1**.[6] This is not the anticipated

(1) (a) W. A. White and H. Weingarten, *J. Org. Chem.*, **32**, 213 (1967). (b) H. Weingarten, J. P. Chupp, and W. A. White, *ibid.*, 3246 (1967).

(2) J. D. Wilson and H. Weingarten, *Can. J. Chem.*, **48**, 983 (1970).

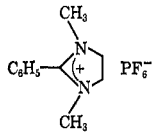
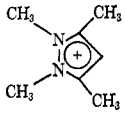
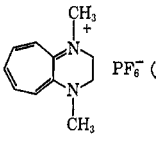
(3) After this work was completed, a brief report of the preparation of some complex cyclic amidinium ions by a similar procedure was published: R. Ian Fryer, J. V. Earley, G. F. Field, W. Zally, and L. H. Stembach, *J. Org. Chem.*, **34**, 1143 (1969).

(4) R. T. Cowdell and G. W. A. Fowles, *J. Chem. Soc.*, 2522 (1960).

(5) H. Weingarten and W. A. White, *J. Amer. Chem. Soc.*, **88**, 850 (1966); *J. Org. Chem.*, **31**, 2874 (1966).

(6) This was verified experimentally by observing the nmr spectra of mixtures of **1** with the conjugate base of **3**, propenylidenebis(dimethylamine), and of **3** with vinylidenebis(dimethylamine). The equilibrium mixture was found to consist almost entirely of **3** and vinylidenebis(dimethylamine), the other two components being undetectable by nmr; thus **3** is *at least* one order of magnitude weaker an acid than **1**.

TABLE I
PRODUCTS FORMED BY $TiCl_4$-PROMOTED AMINATIONS AND THEIR PHYSICAL CONSTANTS

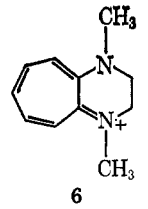
Product[a]	Registry no.	Yield, %	Mp or bp, °C (Torr)	Nmr, τ (rel area)	$\lambda_{max}^{CH_3CN}$, nm (log ϵ)
$HC[N(CH_3)_2]_2^+ PF_6^-$	23645-54-7	37	166–168	3.9 s (1), 7.1 s (12)[d]	*b*
$CH_2{=}C[N(CH_3)_2]_2$ (2)		39	115	6.6 s (2), 7.5 s (12)[e]	228 (3.36)
$CH_3CH_2C[N(CH_3)_2]_2^+ Cl^-$ (3)		70[c]	*c*	6.7 s (12), 7.1 q (2), 8.8 t (3), J = 7.5 Hz[f]	
$Cl_2C{=}C[N(CH_3)_2]_2$	10596-52-8	33	46 (2)	7.6 s[e]	272 (3.73)
$C_6H_5CH{=}C[N(CH_3)_2]_2$	10596-51-7	50	62 (0.2)	3.1 m (5), 5.5 s (1), 7.3 s (6), 7.4 s (6)[e]	233 (3.89), 242 sh, 317 (4.14)
	23645-55-8	31	118.5–119.5	2.3 m (5), 5.9 s (4), 7.0 s (6)[d]	
$(CH_3)_2NC(CH_3){=}CHC(CH_3){=}N(CH_3)_2^+ BF_4^-$ (4)		78	230 dec	5.1 s (1), 6.9 s (12), 7.9 s (6)[d]	344 (4.58)[g]
 Cl^- (5)		23	255 dec	3.6 s (1), 6.2 s (6), 7.7 s (6)[d]	233 (3.39)
 PF_6^- (6)		27	217–218	2.6 m (5), 6.0 s (4), 6.4 s (6)[d]	268 (4.53), 362 (4.11) 440 (3.95)

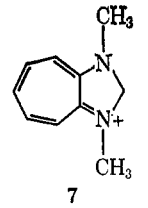
[a] Where salts with anions other than chloride are given, the halide was exchanged for the complex fluoro salt after the amination reaction. The chloride salts of these cations are not stable to storage, either because of hygroscopicity or photo- or oxidative degradation. Yield and physical data are for the complex fluoro salts except for **4** where the yield of the chloride salt is reported. [b] Literature $\lambda_{max}^{H_2O}$ 224 nm (log ϵ 4.076): R. B. Lund, Ph.D. Thesis, University of Washington, 1960. [c] This salt was converted directly into its conjugate base for analysis. See Experimental Section. The nmr spectrum quoted was obtained by adding acid to a solution of the conjugate base. [d] CD_3CN solution, TMS internal standard. [e] Benzene solution, TMS internal standard. Agreed with data presented: H. Weingarten and W. A. White, *J. Amer. Chem. Soc.*, **88**, 850 (1966); *J. Org. Chem.*, **31**, 2874 (1966). [f] Agrees with spectrum of authentic compound reported: C. F. Hobbs and H. Weingarten, *J. Org. Chem.*, **33**, 2385 (1968). [g] Literature $\lambda_{max}^{CH_3CN}$ 345 nm (log ϵ 4.57): J. Kucera and Z. Arnold, *Collect. Czech. Chem. Commun.*, **32**, 1704 (1967).

result, for substitution of methyl for hydrogen on carbon normally *increases* the acidity; *e.g.*, CH_3NO_2 exhibits a pK_A of 10.2 and $CH_3CH_2NO_2$ a pK_A of 8.5.[7,8] In this case, however, the possibility exists for nonbonded interactions between the C- and N-methyl groups in the planar conjugate base, which would be relieved by rotation upon protonation. This would tend to destabilize the conjugate base and decrease the acidity of **3** compared with that of **1**.

The reaction of N,N-dimethylisobutyramide with dimethylamine and titanium tetrachloride was unusual in that it appeared to stop at an intermediate complex stage. Examination of the crude reaction mixture by nmr showed no evidence for either the tetramethylamidinium ion or its conjugate base; however, vacuum distillation, virtually under pyrolysis conditions, of the crude product gave a small yield of the conjugate base, 2-methylpropenylidenebis(dimethylamine).

The electronic spectrum of **6** merits some comment in that it differs considerably from that of its homolog **7**. Brasen, Holmquist, and Benson, who first prepared **7**, reported[10] the uv spectral values $\lambda_{max}^{CH_3CN}$ (log ϵ) 280 (4.95), 335 sh, 362 (4.04), and 375 nm (3.56), while we find **6** to exhibit the values $\lambda_{max}^{CH_3CN}$ (log ϵ) 268 (4.53), 362 (4.11), and 440 nm (3.95). However, **6** is bright yellow while **7** is reported to be red, indicating either that **7** possesses an undetected band above 450 nm or that it "tails" very strongly into the visible. No satisfactory rationale is at hand for these changes in spectra upon homologation, particularly the shift of the short-wavelength band to higher energy.


6


7

The nmr spectrum of **6** indicates that most of the charge in the system resides on the nitrogen atoms. The ring protons resonate at a rather higher field position (centered at τ 2.6) than typical tropenylium ions,[11] while the chemical shift of the N-methyl groups (τ 6.4) is at the low end of the range, where amidinium ion methyls are found.[12]

During the course of an extensive investigation into the electrochemistry of vinylamines,[13] **4** was

(7) F. C. Bordwell, W. J. Bogle, Jr., J. A. Hautala, R. H. Imes, and K. C. Yee, Preprints, Division of Petroleum Chemistry, American Chemical Society, Vol. 13, No. 2, p A25, 1968.

(8) From its reaction with dimethylamine, we can estimate that **1** exhibits a pK_A of 12 (dimethylammonium ion, pK_A = 10.7); it is thus almost as strong an acid as nitromethane. The tetramethylamidinium group must therefore be considered one of the most strongly acidifying methyl substituents.[9]

(9) D. J. Cram, "Fundamentals of Carbanion Chemistry," Academic Press Inc., New York, N. Y., 1965, Chapters 1 and 3.

(10) W. R. Brasen, H. E. Holmquist, and R. E. Benson, *J. Amer. Chem. Soc.*, **83**, 3125 (1961).

(11) T. J. Pratt, R. B. Medz, W. R. Gresham, H. J. Dauben, Jr., and K. M. Harmon, to be published; K. M. Harmon, personal communication, 1968.

(12) *Cf.* the chemical-shift data in Table I.

(13) J. M. Fritsch and H. Weingarten, Abstracts, Midwest Regional Meeting of the American Chemical Society, Manhattan, Kan., Oct 31–Nov 1, 1968; *J. Amer. Chem. Soc.*, **90**, 763 (1968); **92**, in press.

studied and found to undergo in CH_3CN an irreversible one-electron reduction at -1.7 ± 0.1 V *vs.* sce,[14] and a *reversible* one-electron oxidation at +1.31 V. The product of the oxidation has a lifetime ($\tau_{1/2}$ = 0.6 sec[15]) too short for its structure easily to be proved, but it is probably the dication radical of **4**. It seems likely that other vinylogous amidinium ions will be found to undergo this kind of oxidation; perhaps in favorable circumstances dication radical salts will be isolated.

Derivatives of the products discussed in this paper bearing different substituents on nitrogen can be obtained simply by allowing the salt to react with an excess of an amine with the desired substituents. Thus **4** was converted into the pyrazolium ion **5** by allowing it to stand overnight at room temperature in a CH_3CN solution containing excess 1,2-dimethylhydrazine. Because of the reactivity, availability, and volatility of dimethylamine, the preferred method of preparing variously substituted amidinium and vinylogous amidinium salts should be first to prepare the tetramethyl compound by the method outlined here and then to exchange the amine groups.

Experimental Section

Except where otherwise noted, chemicals and solvents used in this investigation were the best grade available from Fisher Scientific, Matheson Coleman and Bell, or Aldrich Chemical Co. Melting points and boiling points were recorded uncorrected. Nmr spectra were obtained using a Varian Associates A-60 spectrometer, with TMS as an internal standard; ir spectra were obtained on KBr disks using a Beckman IR-4 spectrophotometer; ultraviolet spectra were obtained using a Cary 14 spectrophotometer.[16]

N,N-Dimethyl-4-dimethylamino-3-penten-2-immonium Fluoroborate (4). Method A.—Acetylacetone (10.0 g, 0.1 mol) and dimethylamine (45 g, 1 mol) were dissolved in cold pentane (400 ml) in a 1-l. round-bottom flask equipped with stirrer, N_2 inlet, and addition funnel. This mixture was cooled to $-70°$ in a Dry Ice–acetone bath, and to it was added $TiCl_4$ (19 g, 0.1 mol), neat and in small portions. The resulting dark suspension was allowed to warm slowly to room temperature (25°) and to stir at that temperature for 12 hr. The now colorless mixture was filtered; the filter cake was washed with pentane and then dissolved in 200 ml of dry acetonitrile. Anhydrous K_2CO_3 (*ca.* 60 g) was added to this solution [to destroy $(CH_3)_2NH_2Cl$] and the resulting mixture was allowed to stand with occasional agitation for 0.5 hr. The solid was then filtered off and the resulting solution was evaporated to dryness, leaving crude **4**. Recrystallization from CH_2Cl_2–ether yielded 14.7 g (78%) of **4** (Cl^- salt) as hygroscopic, colorless crystals. The chloride was converted into the fluoroborate salt by shaking a CH_2Cl_2 solution of the salt with two successive 50-ml portions of saturated aqueous $NaBF_4$ and washing the aqueous layers with CH_2Cl_2 to recover **4**. The CH_2Cl_2 solutions were combined, dried, and evaporated under vacuum to leave 14.3 g (64%) of **4** BF_4^- salt, which was identified by its nmr and uv[17] spectra. The physical properties of **4** are given in Table I.

Amination of N,N-Dimethylpropanamide. Method B.—In a 250-ml pressure bottle were placed N,N-dimethylpropanamide (5.05 g, 0.05 mol) and $TiCl_4$ (5.3 g, 0.028 mol). The bottle and its contents were cooled in Dry Ice and anhydrous dimethylamine (18 g, 0.40 mol) was added carefully. The bottle was capped and allowed to warm to ambient temperature and stand for 24 hr with occasional shaking. It was then cooled again and opened, and cold, dry pentane (20 ml) was added. The resulting slurry was filtered and the filter cake was allowed to dry. Nmr analysis of the filter cake showed the presence of dimethylammonium ion and N,N,N′,N′-propanamidinium ion (**3**) only.

The amidinium salt was converted into its conjugate base by placing the filter cake in a distillation flask along with 1,5-diazobicyclo[4.3.0]non-5-ene (50 g) (a cyclic amidine) and heating the mixture to 100° until it completely liquefied. The pressure was reduced to 10 Torr, and the pot temperature was gradually raised to 140°. The distillate was caught in a Dry Ice cooled receiver. Redistillation afforded 4.5 g (70%) of propenylidenebis(dimethylamine), bp 52° (33 Torr), $n^{25}D$ 1.4567 [lit.[5] bp 74° (80 Torr), $n^{25}D$ 1.4552]. The nmr spectrum was identical with that reported previously.[5]

Tetramethylformamidinium Hexafluorophosphate.—Dimethylformamide (7.3 g, 0.10 mol) and dimethylamine (20 ml, 0.3 mol) were allowed to react with $TiCl_4$ (5.5 ml, 0.05 mol) for 8 hr by method A. The filtrate from the reaction mixture was extracted twice with 100-ml portions of CH_2Cl_2; the resulting solutions were combined and evaporated to dryness under vacuum. The residue was dissolved in a minimum quantity of methanol and added to a hot, saturated solution of $NaPF_6$ (25 g) (Ozark–Mahoning Corp.) in methanol. Anhydrous K_2CO_3 (*ca.* 10 g) was added, and the solution was warmed for a few minutes, filtered, and allowed to cool. The crystals which formed were filtered off and the filtrate was evaporated to dryness. The residue was extracted with several portions of CH_2Cl_2, which was in turn evaporated to dryness. This residue was recrystallized from CH_2Cl_2–Et_2O to give, when combined with the original crop, 18 g (73%) of tetramethylformamidinium hexafluorophosphate, which was identified by its nmr spectrum.[18] However, yields of the salt prepared by this method are highly variable, largely because it must be separated from by-product $(CH_3)_2NH_2Cl$. In fact, we have found the procedure of Arnold[19] to be the preferred method for preparing tetramethylformamidinium salts; CO_2 is the only by-product here [however, scrupulously dry $HCON(CH_3)_2$ must be employed as the starting material].

Vinylidenebis(dimethylamine) (2).—To a solution of N,N-dimethylacetamide (48.7 g, 0.56 mol) in dimethylamine (300 g, 6.67 mol) in a 50-ml round-bottom flask equipped with stirrer, Dry Ice reflux condenser, dropping funnel, and N_2 inlet, cooled in a Dry Ice–acetone bath, was added, dropwise with stirring, titanium tetrachloride (68.4 g, 0.36 mol) in pentane (100 ml). This mixture was allowed to warm to ambient temperature and stir at that temperature for 18 hr, by which time the original dark color had faded. The mixture was recooled and filtered under nitrogen, the filter cake being washed repeatedly with dry pentane. The filtrates and washings were combined and distilled to yield 24.8 g (37%) of vinylidenebis(dimethylamine), bp 115°, $n^{25}D$ 1.4500. The nmr spectrum (Table I) was identical with that of an authentic sample.

The dry filter cake was stirred with an additional 300 g of dimethylamine at reflux for 4 hr, and then filtered and washed as before. Distillation of the filtrate and washings gave an additional 6.9 g (11%, total 48%) of **2**.

2,2-Dichlorovinylidenebis(dimethylamine).—Using method A, N,N′-dimethyldichloroacetamide (15.6 g, 0.1 mol) and dimethylamine (41.0 g, 0.9 mol) were allowed to react with $TiCl_4$ (5.5 ml, 0.5 mol) in ether for 72 hr. A yield of 6.3 g (33%) of 2,2-dichlorovinylidenebis(dimethylamine) was isolated by distillation, bp 46° (2 Torr) [lit.[5] bp 55° (3 Torr)].

2-Phenylvinylidenebis(dimethylamine).—In a 250-ml pressure bottle, following method B, N,N-dimethylphenylacetamide (8.15 g, 0.05 mol) and $TiCl_4$ (3.1 ml, 0.028 mol) were allowed to react with dimethylamine (18 g, 0.40 mol) for 48 hr at 25°. Distillation gave 4.7 g (50%) of 2-phenylvinylidenebis(dimethylamine), bp 60–62° (0.2 Torr), $n^{25}D$ 1.5889 [lit.[5] bp 80° (0.9 Torr), $n^{25}D$ 1.5905]. The nmr spectrum was identical with that reported.[5]

1,2,3,5-Tetramethylpyrazolium Chloride.—By method A, 1,2-dimethylhydrazine dihydrochloride (2.66 g, 0.02 mol), acetylacetone (2.0 g, 0.02 mol), and triethylamine (10.1 g, (0.1 mol) were allowed to react with $TiCl_4$ (3.8 g, 0.02 mol) in THF solution for 4 days. The product was isolated by extracting the filtrate from the completed reaction with hot CH_3CN and recrystallizing the residue from evaporation of the resulting solution in CH_2Cl_2.

1,4-Dimethyl-1,2,3,4-tetrahydrocyclohepta[*b*]pyrazinium Hexafluorophosphate (6).—Method A was used. Tropolone (12.2 g,

(14) In DMF, $E_{1/2}$ (red) = −1.64 V: A. Holy, J. Krupicka, and Z. Arnold, *Collect. Czech. Chem. Commun.*, **30**, 4127 (1965).

(15) Estimated by cyclic voltammetry.

(16) We thank Mrs. N. K. Edelman and Mrs. J. S. Wager for making many of these measurements.

(17) J. Kucera and Z. Arnold, *Collect. Czech. Chem. Commun.*, **32**, 1704 (1967).

(18) R. B. Lund, Ph.D. Thesis, University of Washington, 1960.

(19) Z. Arnold, *Collect. Czech. Chem. Commun.*, **24**, 760 (1958).

0.1 mol), N,N′-dimethylethylenediamine (35.2 g, 0.4 mol), and $TiCl_4$ (19 g, 0.1 mol) were allowed to react for 6 days at 25° in ether. The reaction mixture was filtered and the precipitate was extracted with CH_2Cl_2 for 24 hr using a Soxhlet extractor. The resulting yellow solution was evaporated to dryness and the residue was treated with a solution of $NaPF_6$ (16.8 g, 0.1 mol) in hot methanol. On cooling, 1,4-dimethyl-1,2,3,4-tetrahydrocyclohepta[*b*]pyrazinium hexafluorophosphate crystallized out. The mother liquor was evaporated to dryness and the residue was extracted with hot CH_2Cl_2 to recover the remaining product. The two fractions were combined and recrystallized from CH_2Cl_2–Et_2O. Although it is apparently stable when crystalline, **6** decomposes quite rapidly in solution, possibly through oxidation; the chloride salt is quite sensitive in this respect.

Anal. Calcd for $C_{11}H_{15}N_2PF_6$: C, 41.26; H, 4.72; N, 8.75; F, 35.60. Found: C, 41.46; H, 4.58; N, 8.55; F, 35.69.

2-Phenyl-1,3-dimethylimidazolinium Hexafluorophosphate.—By method A, benzoic acid (6.1 g, 0.05 mol) and N,N′-dimethylethylenediamine (18 g, 0.2 mol) were allowed to react with $TiCl_4$ (5.6 ml, 0.051 mol) in THF for 48 hr. The filter cake from the reaction mixture was treated with CH_2Cl_2 to dissolve product, which was recovered by evaporation of the CH_2Cl_2. The chloride was exchanged for PF_6^- and the product was recrystallized from THF to yield 5.0 g (31%) of 2-phenyl-1,3-dimethylimidazolinium hexafluorophosphate, mp 118–120°.

Anal. Calcd for $C_{11}H_{15}N_2PF_6$: C, 41.26; H, 4.72; N, 8.75; F, 35.60. Found: C, 40.87; H, 4.75; N, 8.67; F, 35.61.

Registry No.—Titanium tetrachloride, 7550-45-0; **2**, 815-62-3; **4**, 23645-56-9; **5**, 23649-59-4; **6**, 23645-57-0.

Direct Fluorination of Amides[1]

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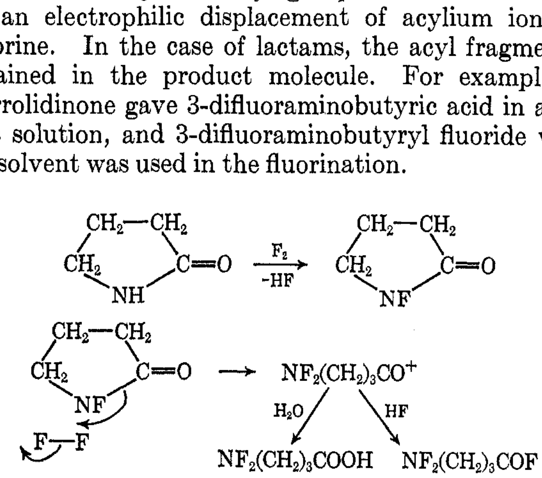
The fluorination of secondary amides was shown to be a general method for the synthesis of difluoramino compounds and N-alkyl-N-fluoroamides. Formation of difluoramino compounds by the displacement of acylium ions was evidenced by the isolation difluoramino acids from lactams and 2-difluoraminoethanol esters from N-acylethanolamines. Some chemical properties of difluoramino acids are described. Alkylfluoroammonium salts were prepared by the reaction of N-alkyl-N-fluoroamides with sulfuric acid. The fluorination of cyclohexanecarboxamide gave cyclohexyl isocyanate and cyclohexylcarboxylic acid, apparently by hydrolysis of the difluoroamide. Oxidation of the fluorination product of acetamide gave tetrafluorohydrazine.

The direct fluorination of alkyl carbamates results in replacement of one or both hydrogens on nitrogen by fluorine,[2] whereas the fluorination of alkyl N-alkylcarbamates results in replacement of NH and subsequently acyl groups.[3] Fluorination studies of amides[4] have been limited to acetamide and N-methylacetamide. Aqueous fluorination of acetamide was reported to give only acetic acid, carbon dioxide, nitrous oxide, and a trace of tetrafluorohydrazine, and that of N-methylacetamide was reported to give acetic acid, carbon dioxide, and a 7% yield of difluoraminomethane. The present paper describes the fluorination of a variety of amides to give N-fluoroamides and difluoramino alkanes, as well as rearrangement products.

Products of the fluorination of secondary amides are shown in Table I. The fluorinations were generally conducted using solutions or suspensions of the substrates in water or acetonitrile, although in several cases no solvent was used. The reactions are similar to those of carbamates in that successive fluorination of NH and fluorinolysis of acyl groups takes place. The rates of the two reactions are of the same order of magnitude, and considerable amounts of difluoramino alkanes are formed, even at low fluorine to substrate ratios. The reactions, however, are characterized by high selectivity toward nitrogen and only two CH fluorination/products, 1,3-bis(difluoramino)-1-fluoropropane and 2-difluoraminoethyl fluoroacetate, were isolated in this work. As a practical synthesis method for difluoramino alkanes, the fluorination of secondary amides is comparable with that of carbamates, and therefore provides a more convenient choice of starting materials. The intermediates, N-fluoroamides, are isolated readily by conventional methods.

The products were characterized by elemental analysis and spectral data, or by comparison with authentic samples. Methyldifluoramine and ethyldifluoramine were prepared previously by reactions of N_2F_4 with alkyl iodides.[5] β-Difluoraminopropionic acid was prepared previously by the addition of difluoramine to acrylic acid,[6] and 1,3-bis(difluoramino)propane and 2-difluoraminoethanol, by the fluorination of the corresponding carbamates.[3]

The fluorinolysis of acyl groups can be rationalized as an electrophilic displacement of acylium ions by fluorine. In the case of lactams, the acyl fragment is retained in the product molecule. For example, 2-pyrrolidinone gave 3-difluoraminobutyric acid in aqueous solution, and 3-difluoraminobutyryl fluoride when no solvent was used in the fluorination.



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