by pyridine, freed the amido function for nucleophilic attack on another molecule of fluoroacetone.

Acetylation of IV under acidic conditions gave VI, VII, or VIII.

Acetic anhydride with a few drops of concentrated sulfuric acid gave only VI, diacetylurea, while monoacetyl urea VII was obtained with acetic anhydride and catalytic amounts of either methane- or *p*-toluene sulfonic acid. Compounds VI and VII were probably formed *via* the acetylation of urea which was presumably generated by the acid-catalyzed hydrolysis of IV. These compounds were identified by a comparison of their infrared spectra with those of authentic samples and mixture melting points.

When IV was heated with acetyl chloride at reflux for 1 hr. a 33% yield of a monoacetylated derivative VIII was obtained. This was shown to be the N-acetyl derivative of IV by the presence of the hydroxyl group (2.95) and absence of the primary amide moiety (3.05 μ) in its infrared spectrum. Furthermore, treatment of VIII with amines gave the corresponding amine salts. Its proton n.m.r. spectrum was also consistent with the assigned structure and its F^{19} n.m.r. spectrum showed a sharp singlet[11] at $\delta_{CFCl_3} = 83.8$ p.p.m.

All attempts to prepare the acetates of the amide and carbamate adducts (IIIa–i) employing acid and basic conditions resulted in failure. Either the adducts were recovered unchanged or were hydrolyzed to the amides and fluoroacetone hydrates.

Experimental

The F^{19} and H′ n.m.r. spectra were obtained with a Varian high-resolution spectrophotometer Model V-4302B. The spectra were calibrated in parts per million displacements from the external primary standards trichlorofluoromethane and tetramethylsilane.

Amide–Fluoroacetone Adducts.—To a stirred solution of 0.2 mole of acetamide in 150 ml. of tetrahydrofuran at room temperature was introduced 0.24 mole of fluoroacetone. The rate of addition was controlled so that the temperature of the reaction mixture did not exceed 50°. After the addition was complete, the mixture was stirred for an additional 30 min. and allowed to cool to room temperature. Removal of the solvent at reduced pressure gave the crude product which was distilled or recrystallized.

Carbamate–Fluoroacetone Adducts.—To a solution of 0.1 mole of carbamate in 40 ml. of acetonitrile nitrile was added 0.11 mole of the fluoroacetone. This was kept in a stoppered pressure bottle with occasional shaking for 5 days. After removal of the solvent under reduced pressure, the crude product was recrystallized from toluene.

Urea–Fluoroacetone (1:1) Adducts.—The fluoroacetone (0.2 mole) was added to 0.2 mole of the urea in tetrahydrofuran at 40° over a 30 min. period with stirring. The reaction mixture was stirred at 40° for an additional 30 min. and was allowed to cool to room temperature. After evaporating the solution to one-third volume, it was chilled to −60° and filtered to give the solid product.

Pyridine Salt of Urea–Fluoroacetone (1:2) Adduct.—To a solution of 2.4 g. (0.03 mole) of pyridine in 40 ml. of tetrahydrofuran was added 7.8 g. (0.03 mole) of IV (R = CF_2Cl) followed by 6.0 g. (0.03 mole) of *sym*-dichlorotetrafluoroacetone. The reaction mixture was stirred at room temperature for 2 days. Removal of solvent under reduced pressure gave 14.0 g. of a crude solid which was triturated with hexane leaving 13.0 g. (80%) of a white solid, m.p. 91–95°. Recrystallization from a cold ether–hexane mixture raised the melting point to 96–97°.

Anal. Calcd. for $C_{12}H_9Cl_4F_3N_2O_3$: C, 26.8; H, 1.7; N, 7.8. Found: C, 26.7; H, 1.8; N, 7.5.

Urea–Fluoroacetone (1:2) Adducts.—The pyridine salt of V, 0.5 g. (0.01 mole), was stirred with 10 ml. of 1:1 hydrochloric acid for 30 min. The solid was filtered and was dissolved in methylene chloride, washed with water, and dried over anhydrous magnesium sulfate. Removal of the solvent under reduced pressure gave 0.2 g. (50%) of a white solid, m.p. 90–91°.

Anal. Calcd. for $C_7H_4Cl_4F_3N_2O_3$: N, 6.1. Found: N, 6.3.

Acetylation of the Urea–Hexafluoroacetone 1:1 Adduct. A.—A mixture of 5.7 g. (0.025 mole) of IV, 5.1 g. (0.05 mole) of acetic anhydride, and 2 drops of concentrated H_2SO_4 was heated on a steam bath for 2 hr. The mixture was chilled in a Dry Ice–acetone bath and filtered. The solid was dissolved in methylene chloride, washed with water, and dried; the solvent was removed under reduced pressure. A yield of 1.0 g. (39%) of a white solid, m.p. 150–152° (lit.[12] m.p. 154–155°), was obtained. This was identical in every way with the authentic sample of N,N′-diacetylurea.

B.—A mixture of 2.3 g. (0.01 mole) of IV, 5.1 g. (0.05 mole) of acetic anhydride, and 1 drop of methane sulfonic acid[13] was heated on a steam bath for 5 min. This was worked up in the same manner as A to give a white solid, 0.3 g. (35%), m.p. 217–219° (lit.[12] m.p. 216–217°). This was identical with the authentic sample of N-acetylurea.

C.—A mixture of 18 g. (0.08 mole) of IV and 39 g. (0.5 mole) of acetyl chloride was refluxed for 1 hr. Chilling the mixture and filtration of the solid gave 7.0 g. (33%) of a white solid, m.p. 92–94° identified as N-acetyl N′-2 hydroxyhexafluoroisopropylurea (VIII).

Anal. Calcd. for $C_6H_6F_6N_2O_3$: C, 26.9; H, 2.2. Found: C, 26.8; H, 2.4.

Acknowledgment.—We are indebted to Dr. B. B. Stewart for the n.m.r. spectra, to Mrs. N. Bolan for the infrared spectra, and to Dr. C. Woolf for some helpful discussion.

(12) E. A. Werner, *J. Chem. Soc.*, **109**, 1120 (1916); R. W. Stoughton, *J. Org. Chem.*, **2**, 514 (1937).

(13) When *p*-toluene sulfonic acid was used as a catalyst, the yield was 25%.

Formation of 2-Propyl-5-methyl- and 2-Propyl-4-methyl-Δ^2-oxazolines from the Thermal Decomposition of Phosphoric Amides Derived from 1-Amino-2-propyl and 2-Amino-1-propyl Butyrates

ROGERS F. LAMBERT, GRANT THOMPSON, AND CLIFFORD E. KRISTOFFERSON

Thiokol Chemical Corporation, Wasatch Division, Brigham City, Utah

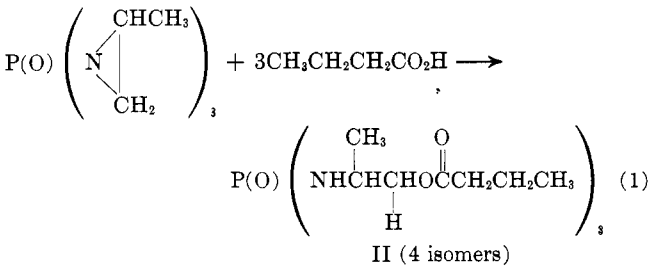
Received April 8, 1964

Tris[1-(2-methyl)aziridinyl]phosphine oxide (I) undergoes imine opening, addition reaction with carboxylic acids to form phosphoric amide derivatives of esters of aminopropanols, which accounts for the utility of I as a cross-linking agent for carboxyl-containing polymers.[1] It has been observed,[2] however, that these cross links are sometimes susceptible to thermal degradation. In an effort to determine a possible mode of cross-link scission, I was treated with butyric acid at reflux temperature in a toluene solution and the thermal decomposition of the phosphoric amide product (II) was investigated (eq. 1).

The reaction of carboxylic acids with three-membered imine rings has been reported to be an S_N2 reaction,

(1) (a) Interchemical Corporation, "MAPO" New Product Bulletin; (b) P. S. Hudson and C. C. Bice, U. S. Patent 3,087,844 (1963).

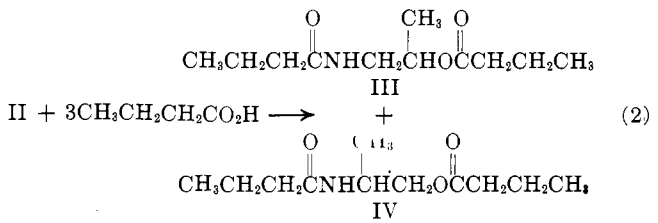
(2) B. M. Wall and G. Thompson, unpublished results.



II (4 isomers) (1)

with attack of the carboxyl group occurring with inversion at the least hindered carbon of the ring.[3] It has been found in this laboratory, however, that although the reaction of butyric acid with I is second order[4] (first order in acid and first order in imine), the attack occurs at both ring positions, as evidenced by the fact that a mixture of 1-amino-2-propanol and 2-amino-1-propanol was obtained from the basic hydrolysis of II. The 2-methyl group apparently offers insufficient hindrance to completely prevent reaction at that position. The product II therefore, is undoubtedly a mixture of the four[5] possible phosphoric amide isomers derived from the two esteramines, 1-amino-2-propyl- and 2-amino-1-propyl butyrates.

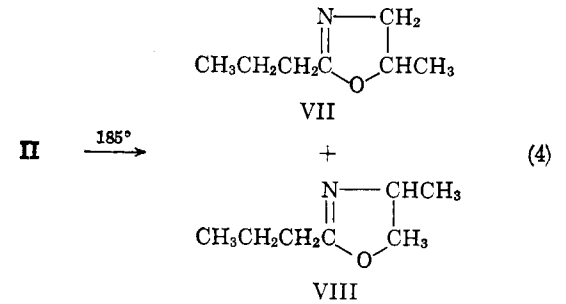
Further characterization of II was obtained by its reaction, at 150°, with excess butyric acid to form a mixture of 1-butyramido-2-propyl (III) and 2-butyramido-1-propyl butyrates (IV) in 62% yield.



(2)

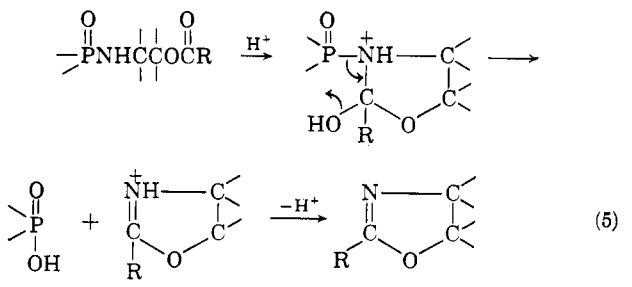
The conversion of phosphoric amides to carboxylic amides in this manner has been previously described.[6] Compounds III and IV were identified by the infrared spectrum and elemental analysis obtained on the mixture, and by hydrolysis to a mixture of the butyramides (V and VI, respectively) of 1-amino-2-propanol and 2-amino-1-propanol, which were converted to 3,5-dinitrobenzoates and separated by fractional crystallization. Several attempts to separate III and IV by gas chromatography and by fractional distillation were unsuccessful.

The thermal decomposition of phosphoric amide derivatives of primary amines is reported[7] to occur under vacuum at temperatures above 200° to form amines and phosphoric imidoamides. The decomposition of II in this manner would produce, as volatile products, the butyryl esters of 1-amino-2-propanol and 2-amino-1-propanol, which would rearrange readily to the amides V and VI.[8] The fact that V and VI are found in volatile products from the decomposition of II in only small amounts, 12% yield based on the stoichiometry of reaction 3, indicates that this is not the major reaction path in this case. Rather, it was found that II decomposes rapidly at a lower temperature (185°) to form a mixture of 2-propyl-5-methyl- (VII) and 2-propyl-4-methyl-Δ^2-oxazolines (VIII), the total oxazoline yield being 60% (20% yield of VII and 40% yield of VIII) based on the complete conversion of II to oxazolines and phosphoric acid. The oxazoline mixture was analyzed by gas chromatography, and the two isomers were characterized as the products of their reactions in basic solution with 3,5-dinitrobenzoyl chloride.[9]



(4)

The ratio of the two oxazolines indicates that the imine opening reaction with butyric acid (reaction 1) occurs approximately twice as fast at the unsubstituted ring position as it does at the substituted ring position. The decomposition of II appears to be acid-catalyzed in that the temperature of rapid decomposition is lowered by acids and raised by bases (see Experimental, Table I). Also, the reaction increases in rate as it progresses, due to accumulation of phosphoric acid. Although the mechanism of oxazoline formation was not investigated further, the following seems to be a reasonable reaction path.



(5)

Experimental[10]

Reaction of Tris[1-(2-methyl)aziridynyl]phosphine Oxide (I) with Butyric Acid.—A solution of 43 g. (0.2 mole) of I[11] and 53 g. (0.6 mole) of butyric acid in 200 ml. of toluene was heated at reflux for 4 hr. The solution was washed with sodium bicarbonate solution and then with water, and the toluene was removed under reduced pressure. The residue was chromatographed on an alumina column. The product II, a mixture of the phosphoric amides derived from 1-amino-2-propyl butyrate and 2-amino-1-

(3) (a) D. H. Powers, Jr., V. B. Schatz, and L. B. Clapp, *J. Am. Chem. Soc.*, **78**, 907 (1956); (b) R. Gherardelli and H. J. Lucas *ibid.*, **77**, 106 (1955); (c) B. Cohen, E. R. Van Artsdalen, and J. Harris, *ibid.*, **74**, 1878 (1952).

(4) G. Harringer and R. F. Lambert, unpublished results.

(5) The three other isomers may be represented by successively reversing the positions of the projecting H and CH_3 on each of the three groups attached to P in structure II.

(6) (a) I. N. Zhmurova, I. Yu. Voitsekhovskaya, and A. V. Kirsanov, *Zh. Obshch. Khim.*, **29**, 2083 (1956); *Chem. Abstr.*, **54**, 8681; (b) J. Klosa, *Arch. Pharm.*, **286**, 253 (1953).

(7) G. M. Kosolapoff, "Organophosphorus Compounds," John Wiley and Sons, Inc., New York, N. Y., 1950, pp. 282, 283.

(8) G. R. Porter, H. N. Rydon, and J. A. Schofield, *J. Chem. Soc.*, 2686 (1960).

(9) E. M. Frey, *J. Org. Chem.*, **15**, 802 (1950).

(10) Microanalyses were by Clark Microanalytical Laboratory, Urbana, Ill.

(11) From Interchemical Corp., distilled under vacuum just prior to use

TABLE 1
THERMAL DECOMPOSITION OF II

Additive	Temp. of rapid dec., °C.	Total oxazoline yield, %
None	185	60
NH_4Cl	140	65
NH_4ClO_4	130	55
p-$CH_3C_6H_4SO_3H$	145	58
H_2SO_4	140	65
H_3PO_4	130	60
NaOMe	185	30
KOH	210	25

propyl butyrate, was obtained as an oil in 54% yield. It showed infrared absorption bands at 5.80 (ester), 8.00 (P=O), 3.00, and 3.12 μ (NH).

Anal. Calcd. for $C_{21}H_{42}N_3O_7P$: C, 52.59; H, 8.82; N, 8.76; P, 6.48. Found: C, 52.31; H, 8.21; N, 9.02; P, 6.83.

Hydrolysis of II.—A solution of II in 25% sodium hydroxide was heated at reflux for 12 hr. Continuous ether extraction gave a mixture of 1-amino-2-propanol and 2-amino-1-propanol, identified by their retention times on a Carbowax–Haloport-F gas chromatography column. From the relative peak areas, it was estimated that the mixture contained 40% of the former and 60% of the latter; more accurate analysis was not attempted.

Reaction of II with Butyric Acid.—A mixture of 48 g. (0.1 mole) of II and 40 ml. (0.43 mole) of butyric acid was heated at 150° in an oil bath for 3 hr. The product was dissolved in ether and washed with sodium bicarbonate solution, and the ether was dried and evaporated. The product, a mixture of the ester amides III and IV, was then distilled: b.p. 125° (1 mm.), yield 40 g. (62%). The infrared spectrum showed bands at 5.75 (ester) and 6.02 μ (amide).

Anal. Calcd. for $C_{11}H_{21}NO_3$: C, 61.36; H, 9.82; N, 6.50; O, 22.29. Found: C, 60.64; H, 9.57; N, 6.38; O, 22.33.

The product was hydrolyzed by heating with 100 ml. of 8% sodium hydroxide solution for 5 hr. Continuous ether extraction gave 14 g. (52% yield) of a mixture of the hydroxyamides, V and VI. Three grams of this mixture was heated with 4 g. of 3,5-dinitrobenzoyl chloride, and by fractional crystallization the 3,5-dinitrobenzoates of V, m.p. 129–130°, and of VI, m.p. 180–182°, were separated. Mixture melting point determinations showed them to be the same as authentic derivatives. Acidification of the sodium hydroxide solution gave butyric acid.

Thermal Decomposition of II.—Twenty-three grams of II (0.048 mole) was placed in a 200-ml. distillation flask at 1mm. The flask was then gradually heated in an oil bath (*ca.* 1°/min.) until the temperature inside the flask reached 185°. At this temperature the material became cloudy. The temperature was then held constant, and the decomposition became very rapid within about 10 min. as evidenced by the formation of large amounts of vapor. The decomposition was complete in 30 min. The product was collected in a Dry Ice cooled receiver and was analyzed by gas chromatography using a Ucon Polar column with xylene as an internal standard. It contained 7.1 g. (40% yield) of 2-propyl-4-methyl-Δ^2-oxazoline (VIII), 3.5 g. (20% yield) of 2-propyl-5-methyl-Δ^2-oxazoline (VII), and 0.8 g. (12% yield based on reaction 3) of a mixture of the butyramides (V and VI) of 1-amino-2-propanol and 2-amino-1-propanol. The ratio of the two oxazolines was the same when unpurified II was decomposed. The oxazoline isomers VII and VIII were separated by fractionation on a Todd column. Each was then reacted at room temperature with 3,5-dinitrobenzoyl chloride in sodium bicarbonate solution[9] to form 1-(3,5-dinitrobenzamido)-2-propyl butyrate, m.p. 140–141°, and 2-(3,5-dinitrobenzamido)-1-propyl butyrate, m.p. 82–83°, respectively. These derivatives did not depress the melting points of the corresponding derivatives from authentic oxazoline samples. The oxazoline products were also identical with authentic samples in boiling points and infrared spectra. The pot residue was an amorphous solid which readily dissolved in water to form an acidic solution.

A series of decomposition experiments was carried out in a manner similar to that described above in which 5% of various acids or bases were mixed with II prior to decomposition. The results are shown in Table I.

1-Butyramido-2-propanol (V).—A mixture of 15 g. (0.2 mole) of 1-amino-2-propanol and 25 g. (0.2 mole) of n-butyl butyrate was heated in an oil bath at reflux temperature for 6 hr. The butyl alcohol was then removed under reduced pressure and the product was distilled: b.p. 166° (10 mm.), yield 45%. A 3,5-dinitrobenzoate was prepared by heating the product with 3,5-dinitrobenzoyl chloride; it had m.p. 130–131° (alcohol–water).

Anal. Calcd. for $C_{14}H_{17}N_3O_7$: C, 49.56; H, 5.05; N, 12.38 Found: C, 49.60; H, 4.78; N, 12.78.

2-Butyramido-1-propanol (VI).—This product was prepared by heating at reflux a mixture of 10 g. (0.13 mole) of 2-amino-1-propanol[12] and 21 g. (0.14 mole) of n-butyl butyrate. The product was obtained in 30% yield: b.p. 126° (mm.), 3,5-dinitrobenzoate m.p. 182–184° (alcohol).

Anal. Calcd. for $C_{14}H_{17}N_3O_7$: C, 49.56; H, 5.05; N, 12.38. Found: C, 49.63; H, 4.99; N, 12.13.

2-Propyl-5-methyl-Δ^2-oxazoline (VII).—This material was prepared from V by a procedure similar to that described by Wenker.[13] The yield was 25%, b.p. 150°, infrared band at 5.95 μ (N=C).

Anal. Calcd. for $C_7H_{13}NO$: C, 66.10; H, 10.30; N, 11.02. Found: C, 65.57; H, 9.67; N, 10.79.

The product was converted to 1-(3,5-dinitrobenzamido)-2-propylbutyrate by stirring with 3,5-dinitrobenzoyl chloride in sodium bicarbonate solution; it had m.p. 139–141° (alcohol–water).

Anal. Calcd. for $C_{14}H_{17}N_3O_7$: C, 49.56; H, 5.05; N, 12.38. Found: C, 49.30; H, 4.81; N, 11.97.

2-Propyl-4-methyl-Δ^2-oxazoline (VIII).—This oxazoline was prepared from VI.[13] The yield was 32%, b.p. 145°, infrared absorption at 5.95 μ (N=C).

Anal. Calcd. for $C_7H_{13}NO$: C, 66.10; H, 10.30; N, 11.02. Found: C, 65.92; H, 10.00; N, 10.94.

2-(3,4-Dinitrobenzamido)-1-propyl butyrate from VIII and 3,5-dinitrobenzoyl chloride underwent reaction in sodium bicarbonate solution giving a product with m.p. 84–85° (alcohol–water).

Anal. Calcd. for $C_{14}H_{17}N_3O_7$: C, 49.56; H, 5.05; N, 12.38. Found: C, 49.63; H, 5.05; N, 12.37.

(12) F. F. Blicke, J. A. Faust, R. J. Warzynski, and J. E. Gearien, *J. Am. Chem. Soc.*, **67**, 205 (1945).

(13) H. Wenker, *ibid.*, **57**, 1079 (1935).

The pK_a Values of Some 2-Aminomidazolium Ions

BAYARD T. STOREY, WALTER W. SULLIVAN, AND CALVIN L. MOYER

Research Laboratories, Rohm and Haas Company, Philadelphia 37, Pennsylvania

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In his book on imidazole and its derivatives, Hofmann[1] states that the properties of 2-aminoimidazole demonstrate that it is best regarded as a guanidine derivative, the 2-aminoimidazolium ion receiving major contributions from structures with the positive charge evenly distributed among all three nitrogens. It is just this even distribution of positive charge which makes guanidine a strong base[2]; major contributions from such structures should result in high basicity for 2-aminoimidazole and its derivatives compared to imidazole. If the 2-aminomidazoles were strong enough bases to be considered derivatives of guanidine rather than of imidazole, it would imply that an amino substituent at the 2-position of the imidazole ring could profoundly alter the imidazole structure. Such an alteration seemed very unlikely. The study reported

(1) K. Hofmann, "The Chemistry of Heterocyclic Compounds," Vol. 6, A. Weissburger, Ed., Interscience Publishers, Inc., New York, N. Y., 1963, pp. 141, 142.

(2) R. P. Bell, "The Proton in Chemistry," Cornell University Press, Ithaca, N. Y., 1959, p. 96.