methylpentyl)urethan; infrared spectrum: N–H at 3450 cm^{-1} (sharp) and 3350 (broad), carbonyl at 1715 cm^{-1}; nmr spectrum: (in δ values): 0.99 (isopropyl-CH_3, doublet, 6.0 H), 1.22 (ethoxy-CH_3, triplet, 3.1 H), 1.50 (CH_3 at C-1, doublet, 3.1 H), 1.5–2.1 (isopropyl-CH, multiplet, 1.7 H), 4.47 (N–C–H, triplet, 1.0 H), 4.08 (ethoxy-CH_2, quartet), 4.0–4.5 (Cl–C–H, multiplet, CH_2 + CH, 3.2 H), and 5.17 (N–H, doublet, 1.0 H).

The mass spectrum showed a parent peak at *m/e* 207 (as expected) and a base peak at 164, corresponding to the loss of $CH(CH_3)_2$, leaving the ion CH_3-$CHCl$-C^+H-$NHCOOEt$. Calcd for $C_6H_{11}ClNO_2$ (ratio of M + 2 to M): 32.4. Found: 31.8. Also, a major peak at 144, corresponding to the loss of H_3C–CHCl, was shown, leaving the ion $(H_3C)_2CH$–C^+H–$NHCOOEt$. Calcd for $C_7H_{14}NO_2$ (ratio of M + 1 to M): 8.2. Found: 8.3.

Neopentylurethan was prepared from neopentylamine (0.35 g, 0.040 mole), ethyl chloroformate (0.04 mole), and triethylamine (0.04 mole) in 15 ml of anhydrous ether with cooling. Analysis on column B showed neopentylurethan to be the only ether-soluble product. The neopentylamine had been prepared by reduction of pivalamide with lithium aluminum hydride; infrared spectrum: N–H at 3470 cm^{-1} (sharp) and 3370 (broad), carbonyl at 1720 cm^{-1}; nmr spectrum (in δ values): 0.90 (*t*-butyl-CH_3, singlet, 9.0 H), 1.20 (ethoxy-CH_3, triplet, 3.3 H), 2.93 (methylene-CH_2, doublet, 2.0 H), 4.08 (ethoxy-CH_2, quartet, 2.0 H), and 5.3–6.0 (N–H, broad, 1.0 H).

Anal. Calcd for $C_8H_{17}NO_2$: C, 60.34; H, 10.76; N, 8.80. Found: C, 60.41; H, 10.90; N, 8.85.

Photolysis of Ethyl Azidoformate in Neopentane. Ethyl azidoformate (0.5 g, 0.004 mole) was placed in a 20-ml silica tube, fitted with a fused silica insulating jacket, and a dewar-type condenser filled with ice–salt mixture. Neopentane (Matheson, 99+% pure) was condensed into the tube, to a volume of 10 ml. Boiling of the neopentane served to mix the components. The solution was irradiated for 3 hr, under reflux. The residue was analyzed on column B at 120°. The two major components were undecomposed ethyl azidoformate and neopentylurethan.

Photolysis of Ethyl Azidoformate in Olefin–Neopentane. Solutions of 0.1 g of ethyl azidoformate in 30–36 ml of the appropriate solutions of *cis*- or *trans*-4-methylpent-2-ene in neopentane were photolyzed for 3 hr, as above, and the reaction residues analyzed on columns A and B. The results are found in Table V.

Acknowledgment. We are greatly indebted to the National Science Foundation for support of this work by Grant GP 3846, and to the National Institutes of Health for a Predoctoral Fellowship to J. S. M.

Small Charged Rings. IX.[1] Expansion of the Azirine Ring[2]

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Abstract: The ring expansion of an azirine has been effected, proceeding through the azirinium salt, generated *in situ*, as a probable intermediate. The representative azirine, 3,3-dimethyl-2-phenyl-1-azirine, on treatment with acetone and perchloric acid (or fluoroboric acid), formed an oxazolinium salt, 4-phenyl-2,2,5,5-tetramethyl-3-oxazolinium perchlorate (or fluoroborate), identified by infrared, ultraviolet, and nmr spectra, and by hydrolysis to ammonium perchlorate and benzoyl dimethyl carbinol. Using deuterium-labeled acetone, it was possible to determine how this moiety took its place in the five-membered ring product: by a mechanistic pathway following 1,3-bond cleavage in the original azirine. The corresponding base, 4-phenyl-2,2,5,5-tetramethyl-3-oxazoline, was obtained from the perchlorate by treatment with alkali. 3,3-Dimethyl-2-phenyl-1-azirine and perchloric acid in ethyl methyl ketone furnished 2-ethyl-4-phenyl-2,5,5-trimethyl-3-oxazolinium perchlorate. The ring expansion of the same azirine with perchloric acid in acetonitrile yielded the hydrated form of 5-phenyl-2,4,4-trimethyl-4H-isoimidazolium perchlorate, namely, 4-hydroxy-4-phenyl-2,5,5-trimethyl-2-imidazolinium perchlorate, the structure of which was established by spectroscopy, by hydrolysis and hydrogenation products, and by chemical interconversions with 4-ethoxy-4-phenyl-2,5,5-trimethyl-2-imidazolinium perchlorate and 4-isopropoxy-4-phenyl-2,5,5-trimethyl-2-imidazolinium perchlorate, the latter also being made independently by ring enlargement of 3,3-dimethyl-2-isopropoxy-2-phenylaziridine in acetonitrile with perchloric acid generated *in situ*. By the use of ^{15}N-labeled acetonitrile in the case of the azirine and mass spectrometric analysis of the product it was possible to determine that the path of incorporation in the final product necessitated cleavage of the 1,3 bond in the azirine. By contrast, the perchloric acid catalyzed methanolysis of 3,3-dimethyl-2-phenyl-1-azirine resulted effectively in 1,2-bond cleavage. Additional ring expansion reactions were realized in the conversion of 3,3-dimethyl-2-methoxy-2-phenyloxirane to 4-methoxy-4-phenyl-2,5,5-trimethyl-2-oxazolinium perchlorate with acetonitrile and perchloric acid and of 3,3-dimethyl-2-isopropoxy-2-phenylaziridine to 5-isopropoxy-5-phenyl-2,2,4,4-tetramethyloxazolidinium perchlorate with acetone and acid.

The ring expansion of aziridinium salts with aldehydes,[3] ketones,[4] and nitriles[5,6] comprises a general family of reactions resulting in the conversion of positively charged three-membered rings to five-membered rings ($③^+ + 2 \rightarrow ⑤^+$). We have extended our study on small-ring heterocycles by taking an azirine under consideration. The azirines, and the related possible azirinium salts, are of special interest because of their comparative relation to aziridinium salts, since the

(1) (a) For the preceding article in this series, see N. J. Leonard, R. Y. Ning, and R. L. Booth, *J. Org. Chem.*, **30**, 4357 (1965). (b) The substance of this article has been presented at the 150th National Meeting of the American Chemical Society, Atlantic City, N. J., Sept 1965, Abstracts, p 19S, and at the 1st Annual Midwest American Chemical Society Meeting, Kansas City, Mo., Nov. 1965, Abstracts, p 40. (c) N. J. Leonard, *Record Chem. Progr.* (Kresger-Hooker Sci. Lib.), **26**, 211 (1965).

(2) This investigation was supported by a research grant (GP 2012) from the National Science Foundation, to whom we are pleased to acknowledge our thanks.

(3) N. J. Leonard, E. F. Kiefer, and L. E. Brady, *J. Org. Chem.*, **28**, 2850 (1963).

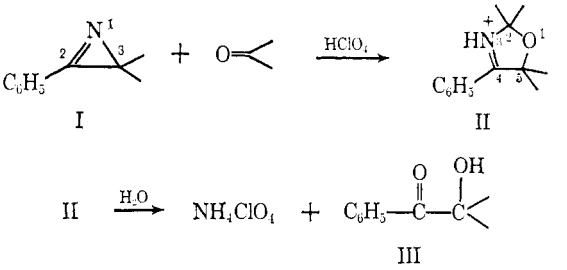
(4) N. J. Leonard, J. V. Paukstelis, and L. E. Brady, *ibid.*, **29**, 3383 (1964).

(5) N. J. Leonard and L. E. Brady, *ibid.*, **30**, 817 (1965).

(6) E. Pfeil and U. Harder, *Angew. Chem.*, **77**, 505 (1965).

double bond introduces greater reactivity into the three-membered ring system.

Azirines are postulated as intermediates in the Neber rearrangement,[7] and the isolation of the first azirine[8] has been confirmed by Cram and Hatch.[9] 3,3-Dimethyl-2-phenyl-1-azirine (I), which can be readily prepared by the method of Parcell[10] from isobutyrophenone dimethylhydrazone methiodide and sodium isopropoxide in isopropyl alcohol, was selected as the prototype in the present study. Our first approach was to try to effect the alkylation of this azirine in order to obtain a close analog for the quaternary aziridinium salts.[11] The attempted benzylation of 3,3-dimethyl-2-phenyl-1-azirine (I) with benzyl bromide and silver perchlorate in acetone as solvent did not give the desired benzylazirinium salt but instead furnished, in 39% yield, a crystalline compound, $C_{13}H_{18}ClNO_5$, which contained the elements of the original azirine plus those of acetone and perchloric acid. The same compound was obtained, in 30% yield, when I was dissolved in a large excess of acetone and treated with 1 equiv of 70% aqueous perchloric acid at −30°. The structure of the product was assigned as 4-phenyl-2,2,5,5-tetramethyl-3-oxazolinium perchlorate (II) on the basis of spectral and chemical data. The infrared spectrum (KBr) showed maxima at 1642 cm^{-1}, indicative of $C{=}N^+$, probably conjugated; 2535 cm^{-1}, indicative of ${=}N^+{-}H$; and 1100 cm^{-1}, confirmatory for perchlorate anion. The ultraviolet spectrum (ethanol) exhibited an absorption maximum at 241 mμ (ε 11,000) consistent with the conjugation portrayed in formula II. The nmr spectrum (DMSO-d_6) showed a multiplet at τ 1.9–2.6 for the five aromatic protons and singlets at τ values −0.06 (one proton, $N^+{-}H$), 8.40 (six protons), and 8.49 ppm (six protons). Differentiation between the pairs of methyl groups responsible for the last two signals was possible by chemical means to be described below. Hydrolysis of the $C_{13}H_{18}ClNO_5$ product gave ammonium perchlorate (94%) and benzoyl dimethyl carbinol (III) (96%), the latter compound being identified by comparing infrared and nmr spectra with those of an authentic sample of the ketol.[12] These hydrolysis products secured the structure assigned (II). The formation of II in the attempted benzylation can be rationalized in one way by assuming that acetone is first benzylated[13] to give the O-benzylacetone oxonium perchlorate which stabilizes itself by loss of a proton as perchloric acid, presumably forming benzyl isopropenyl ether. The perchloric acid thus generated brings about the ring expansion reaction.



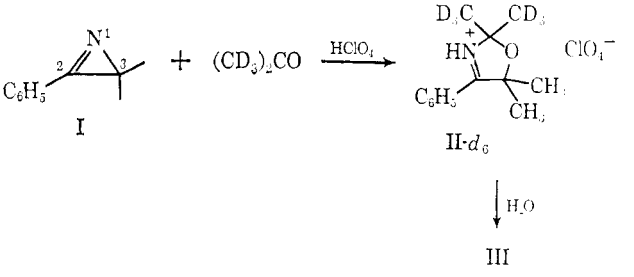
I II

III

The possibility that adventitious water might play a role has not been excluded. The azirine I is stable in acetone solution in the absence of acid, but in acid media it is very sensitive to hydrolysis.[10] Even when the reaction of the azirine was carried out in a huge excess of acetone, with only 1 equiv of 70% aqueous perchloric acid, the hydrolysis product, α-aminoisobutyrophenone perchlorate, could not be avoided.

The *in situ* generation of anhydrous perchloric acid was accomplished by adding anhydrous *p*-toluenesulfonic acid to a solution of the azirine I and silver perchlorate in acetone. The low solubility of silver *p*-toluenesulfonate permitted its removal by filtration or centrifugation, and 4-phenyl-2,2,5,5-tetramethyl-3-oxazolinium perchlorate (II) was isolated in 30% yield. Magnesium perchlorate could be used in place of silver perchlorate. 4-Phenyl-2,2,5,5-tetramethyl-3-oxazolinium fluoroborate was prepared (42% yield) from 3,3-dimethyl-2-phenyl-1-azirine and anhydrous silver fluoroborate in acetone, to which anhydrous *p*-toluenesulfonic acid was added. When a solution of the azirine I in acetone was treated with anhydrous *p*-toluenesulfonic acid at −10°, and the oil remaining upon removal of the solvent was treated with silver perchlorate, none of product II could be isolated. The effectiveness of nonnucleophilic anions (ClO_4^-, BF_4^-) in ring expansion reactions has been demonstrated earlier with the aziridinium salts.[3-5] At this point we have tried the reaction of I with only one other ketone, ethyl methyl ketone, in the presence of perchloric acid (from silver perchlorate and anhydrous *p*-toluenesulfonic acid), obtaining the analogous product, 2-ethyl-4-phenyl-2,5,5-trimethyl-3-oxazolinium perchlorate (15% yield).

It will be noted that partial symmetry exists within structure II due to the nature of the azirine and the ketone selected, leaving an uncertainty as to whether the carbonyl group of acetone appears as atoms 1,2 or 1,5 in the final oxazolinium ring. We therefore selected deuterium labeling as a means of determining whether the reaction path followed is cleavage of the 1,3 or the 2,3 bond of the original azirine (I). The reaction of 3,3-dimethyl-2-phenyl-1-azirine with acetone-d_6 and perchloric acid generated *in situ* furnished hexadeuterated product, II-d_6. The nmr spectrum

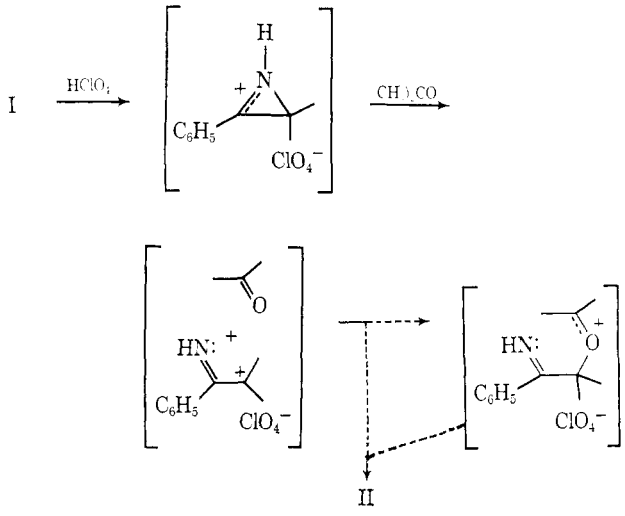


I II-d_6 III

(DMSO-d_6) was essentially that of II but lacking the

(7) C. O'Brien, *Chem. Rev.*, **64**, 81 (1964).
(8) P. W. Neber and A. Burgard, *Ann.*, **493**, 281 (1932).
(9) D. J. Cram and M. J. Hatch, *J. Am. Chem. Soc.*, **75**, 33 (1953).
(10) R. F. Parcell, *Chem. Ind.* (London), 1396 (1963).
(11) Examples of alkylation as a route to quaternary aziridinium salts have been provided by (a) P. E. Fanta, L. J. Pandya, W. R. Groskopf, and H.-J. Su, *J. Org. Chem.*, **28**, 413 (1963); (b) A. T. Bottini and R. L. Van Etten, *ibid.*, **30**, 575 (1965); (c) G. K. Helmkamp, R. D. Clark, and J. R. Koskinen, *ibid.*, **30**, 666 (1965). Isolation of such salts has made possible the determination of the geometry and dimensions of the aziridinium ring by single crystal X-ray analysis by (d) L. M. Trefonas and J. Couvillion, *J. Am. Chem. Soc.*, **85**, 3184 (1963); and (e) L. M. Trefonas and R. Majeste, *Tetrahedron*, **19**, 929 (1963).
(12) (a) C. L. Stevens and E. Farkas, *J. Am. Chem. Soc.*, **74**, 618 (1952); (b) C. L. Stevens, M. L. Weiner, and R. C. Freeman, *ibid.*, **75**, 3977 (1953); (c) C. L. Stevens and J. J. DeYoung, *ibid.*, **76**, 718 (1954).
(13) *Cf.* (a) H. Meerwein and K. Wunderlich, *Angew. Chem.*, **69**, 481 (1957); (b) H. Meerwein, V. Hederich, and K. Wunderlich, *Arch. Pharm.*, **291**, 541 (1958); (c) H. Meerwein, K. Bodenbenner, P. Borner, F. Kunert, and K. Wunderlich, *Ann.*, **632**, 38 (1960).

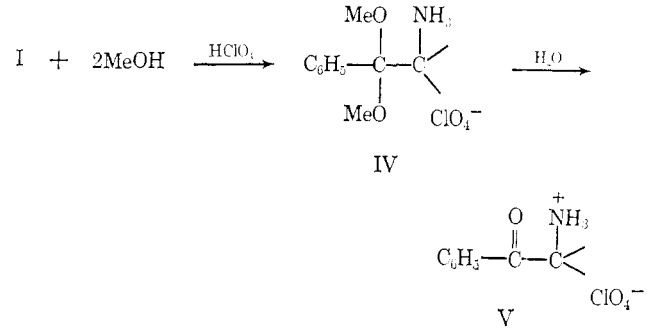
singlet signal at 8.49 ppm. Hydrolysis of the hexadeuterio compound yielded ammonium perchlorate and benzoyl dimethyl carbinol (III) (96%). Since the latter contained no deuterium according to the nmr spectrum, the deuterated methyl groups were fixed thereby at the 2 position of the oxazolinium ring in II-d_6 and the reaction path was established as that of 1,3-bond cleavage in the original azirine. Any plausible mechanistic sequence must accommodate this result. One such sequence would involve the ring opening of the protonated azirine, the intermediacy of a resonance-stabilized carbonium–oxonium ion produced by combination of the initially formed carbonium ion with the ketone carbonyl, and the attack of the nitrogen unshared pair of electrons on the new carbonium ion center to complete the cyclization. A possible compression of the rates of carbonium–oxonium ion formation and N–C bond formation would be equivalent to the omission of one intermediate. A less likely sequence would involve nucleophilic attack of the azirine nitrogen on the conjugate acid of acetone, followed by consecutive steps of 1,3-bond cleavage of the N-substituted azirinium intermediate and reclosure to



give the final oxazolinium ring (II).

The free base corresponding to II, namely, 4-phenyl-2,2,5,5-tetramethyl-3-oxazoline, was obtained by treating II with 1 mole equiv of sodium hydroxide. The resulting oil had the correct analysis for $C_{13}H_{17}NO$ and spectral properties which were consistent with the assigned structure. The only previous report of a 3-oxazoline is that of Gaines and Hansen.[14]

The acid-catalyzed methanolysis of 3,3-dimethyl-2-phenyl-1-azirine (I) led to the formation (99%) of the dimethyl ketal IV of α-aminoisobutyrophenone perchlorate, which upon hydrolysis gave α-aminoisobutyrophenone perchlorate (V). The products were characterized by elemental analysis, infrared, ultraviolet, and nmr spectroscopy (see Experimental Section). The mechanistic sequence which best explains the overall result of 1,2-bond cleavage in the original azirine is as follows: protonation of I, nucleophilic attack by methanol on the iminium bond, cleavage of the 1,2 bond in the intermediate 3,3-dimethyl-2-methoxy-2-phenylaziridine perchlorate to give the more stable



carbonium ion, and reaction of this with the second mole of methanol. Neber's azirine, 3-(2′,4′-dinitrophenyl)-2-methyl-1-azirine, upon ethanolysis in the presence of *p*-toluenesulfonic acid, gave 1-amino-1-(2′,4′-dinitrophenyl)propanone *p*-toluenesulfonate in quantitative yield, indicating exclusive cleavage of the 1,2 bond.[8] Acid-catalyzed hydrolysis of azirines[8,10,15,16] has been reported to occur through attack of the iminium bond. In the case of 3,3-dimethyl-2-phenyl-1-azirine (I), Parcell[10] obtained α-aminoisobutyrophenone hydrochloride only in low yield upon hydrolysis in aqueous hydrochloric acid. The contrast between the reaction of I and perchloric acid with acetone and with methanol probably has its basis in the greater nucleophilicity of methanol and in the potentially greater stabilization of the intermediate formed following initial addition at the 2 position.

Since nitriles had been found to be effective in the ring expansion of aziridinium salts,[5] the reaction of the unsaturated three-membered ring, compound I, with acetonitrile was also investigated. 3,3-Dimethyl-2-phenyl-1-azirine is stable in acetonitrile in the absence of acid, as shown by the observation that the ultraviolet absorption maximum at 243 mμ of a solution of I in acetonitrile was unchanged over a period of 3 months. When perchloric acid was generated *in situ* in such a solution through the use of anhydrous magnesium perchlorate and anhydrous *p*-toluenesulfonic acid, a crystalline product, $C_{12}H_{17}ClN_2O_5$, was obtained in 77% yield. On the basis of the analysis, the product contained, in addition to the expected elements of azirine, acetonitrile, and perchloric acid, one molecule of water, even though the reaction had been carried out trying to maintain anhydrous conditions. Similarly, the reaction of the azirine I in propionitrile with perchloric acid yielded a product, $C_{13}H_{19}ClN_2O_5$, in 66% yield.

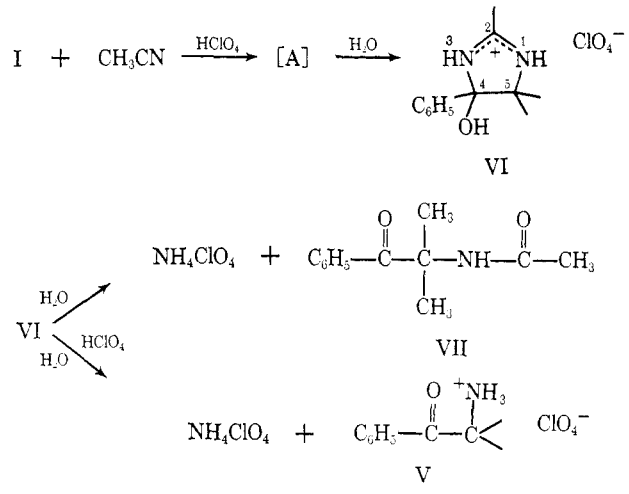
The ultraviolet spectrum of the acetonitrile product, $C_{12}H_{17}ClN_2O_5$, in ethanol showed features typical of a nonconjugated benzene nucleus (see Experimental Section). This observation revealed that the product obtained was not the anticipated 5-phenyl-2,4,4-trimethyl-4H-isoimidazolium perchlorate [A] containing one molecule of water of crystallization. The striking feature of the nmr spectrum of the acetonitrile product is the nonequivalence of the methyl groups. In acetone-d_6, the proton magnetic resonance signals, all singlets, were observed at τ values: 9.11 (3 H), 8.38 (3 H), 7.48 (3 H), 3.71 (1 H), 0.42 (1 H), and 0.20 (1 H), along with a signal at 2.80–2.30, corresponding

(14) J. R. Gaines and G. R. Hansen, *J. Heterocyclic Chem.*, **1**, 96 (1964).

(15) D. F. Morrow and M. E. Butler, *ibid.*, **1**, 53 (1964).

(16) D. F. Morrow, M. E. Butler, and E. C. Y. Huang, *J. Org. Chem.*, **30**, 579 (1965).

to five aromatic protons. The signal at 7.48 corresponds to the methyl group originally present in acetonitrile, as shown by comparison with the spectrum of the propionitrile product. Hydrolysis of $C_{12}H_{17}ClN_2O_5$ in the presence of 1 equiv of perchloric acid gave ammonium perchlorate (76%) and α-aminoisobutyrophenone perchlorate (V) (73%). Hydrolysis in water gave ammonium perchlorate (92%) and α-acetaminoisobutyrophenone (VII) (64%). These hydrolysis experiments secure the moiety C_6H_5–C–C-$(CH_3)_2$ in the original $C_{12}H_{17}ClN_2O_5$. Thus, rearrangement of the *gem*-dimethyl group of the azirine had not occurred in the reaction with acetonitrile and acid. Accordingly, the large difference in chemical shift of the two geminal methyl groups is most likely due to a magnetic anisotropy effect of the phenyl nucleus, and the two methyl groups are fixed in different environments relative to the phenyl ring. The infrared spectrum

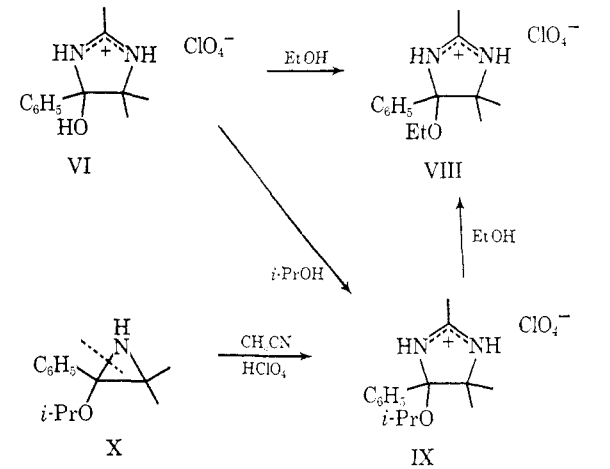


(Nujol) exhibited maxima characteristic of perchlorate anion and phenyl and, especially indicative maxima at 3450 (O–H), 3280 (N–H), 1618, and 1580 cm^{-1}. The last three peaks were suggestive of an amidinium salt grouping, as found in our earlier work with aziridinium salts and nitriles.[5] Hydrogenation of $C_{12}H_{17}ClN_2O_5$ in acetone solution in the presence of platinum gave a product, $C_{12}H_{23}ClN_2O_5$, in 84% yield, in which the oxygen and nitrogen functions were not changed, as adduced by the sustained infrared maxima at 3470 (O–H), 3280 (N–H), 1623, and 1590 cm^{-1}, but in which the benzene ring had been reduced to a cyclohexane, as shown by the absence of magnetic resonance signals for aromatic protons and by the disappearance of the aromatic absorption in the infrared. The accumulated data point to structure VI, 4-hydroxy-4-phenyl-2,5,5-trimethyl-2-imidazolinium perchlorate, for the $C_{12}H_{17}ClN_2O_5$ product, and to 4-cyclohexyl-4-hydroxy-2,5,5-trimethyl-2-imidazolinium perchlorate for its catalytic hydrogenation product.

Compound VI was also obtained from the reaction of the azirine I in a large excess of acetonitrile upon addition of 70% aqueous perchloric acid. α-Aminoisobutyrophenone perchlorate was formed as the by-product, whereas it was not a contaminant when anhydrous perchloric acid was generated *in situ*, as described earlier. Silver perchlorate in combination with anhydrous *p*-toluenesulfonic acid could not be used to generate perchloric acid *in situ* in acetonitrile since silver *p*-toluenesulfonate is soluble in this solvent. Upon addition of anhydrous *p*-toluenesulfonic acid to a solution of the azirine I in acetonitrile, an oily material was obtained. Treatment of the latter with 1 equiv of silver perchlorate in acetone gave impure VI in very low yield. The 2,4,6-trinitrobenzenesulfonate corresponding to VI was obtained (57% yield) from the reaction of I in acetonitrile upon addition of 1 equiv of 2,4,6-trinitrobenzenesulfonic acid.

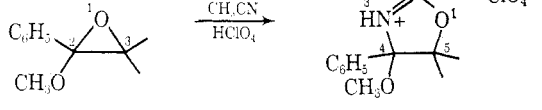
Chemical substantiation for structure VI, 4-hydroxy-4-phenyl-2,5,5-trimethyl-2-imidazolinium perchlorate, was obtained by interconversions using ethanol and isopropyl alcohol. When VI was heated under reflux with ethanol, a new compound $C_{14}H_{21}ClN_2O_5$ (VIII), was obtained in 92% yield. The infrared spectrum (chloroform) showed maxima at 3210 (N–H), 1623, and 1575 cm^{-1} (symmetric and antisymmetric compound vibrations of N–C–N) characteristic for the amidinium moiety. In the nmr spectrum in deuteriochloroform three methyl groups were indicated by the singlet proton signals at τ values 9.25, 8.45, and 7.52 ppm, the ethyl group by a triplet (3 H) at 8.88 (J = 7 cps) and a quartet (actually closer to two overlapping quartets with total integration for two protons) centered at 6.7, a phenyl group by a rather sharp signal centered at 2.60, and two N–H protons at τ 0.97 and 0.50 ppm. Prolonged heating of compound VIII in ethanol did not cause further reaction. When compound VI was heated under reflux with isopropyl alcohol, an analogous product, $C_{15}H_{23}ClN_2O_5$ (IX), was obtained in 87% yield. This compound had the same infrared characteristics as VIII. The nmr spectrum in deuteriochloroform showed, in addition to the three methyl groups as singlets at τ values 9.26, 8.41, and 7.51 ppm, the isopropyl protons as a pair of doublets at 9.01 and 8.89 (J = 6 cps), and a multiplet at 6.3. It was possible to complete the cycle by converting the isopropoxy derivative IX to the ethoxy derivative VIII by refluxing in ethanol. During all of these alcoholyses, only the hydroxyl group of VI is replaced by an alkoxy group. The rest of the molecule is unchanged, providing further indication of the stability of the amidinium salt moiety.

To provide further chemical basis for structure proof, compound IX was synthesized also by a ring expansion reaction, *which is novel in that it involves for the first time the enlargement of an alkoxyaziridine ring.* The treatment of 3,3-dimethyl-2-isopropoxy-2-phenylaziridine (X)[10] in acetonitrile with perchloric acid gen-



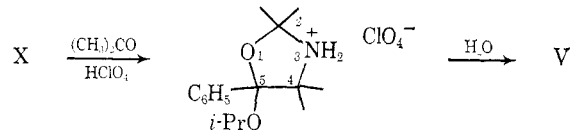
erated *in situ* gave 4-isopropoxy-4-phenyl-2,5,5-trimethyl-2-imidazolinium perchlorate (IX) in 57% yield, identical with the product obtained from VI and isopropyl alcohol. The product VIII obtained from the reaction of either VI or IX with ethanol is therefore 4-ethoxy-4-phenyl-2,5,5-trimethyl-2-imidazolinium perchlorate. The treatment of 3,3-dimethyl-2-isopropoxy-2-phenylaziridine (X) with propionitrile and perchloric acid gave a product, $C_{16}H_{23}ClN_2O_5$, which only differs from IX in having an ethyl group rather than a methyl group at C-2.

Parallel to the ring expansion of an alkoxyaziridine is the expansion of an epoxy ether in acetonitrile, which has been described in a recent note by Temnikova and Zhesko[17] as taking place with tin chloride as a catalyst. Under the reaction conditions employed for 3,3-dimethyl-2-phenyl-1-azirine (I) and 3,3-dimethyl-2-isopropoxy-2-phenylaziridine (X), namely, anhydrous perchloric acid in acetonitrile, 3,3-dimethyl-2-methoxy-2-phenyloxirane (XI)[12a] yielded (75%) an analogous product, $C_{13}H_{18}ClNO_6$. The structure 4-



XI XII

methoxy-4-phenyl-2,5,5-trimethyl-2-oxazolinium perchlorate (XII) was assigned on the basis of the infrared spectrum (chloroform), which showed maxima at 2650 (=N^+—H) and 1635 cm^{-1} (C=N^+), an ultraviolet spectrum having features typical of a nonconjugated phenyl ring, and hydrolysis in boiling water, which yielded ammonium perchlorate (95%) and benzoyl dimethyl carbinol acetate (95%). The nmr spectrum ($CDCl_3$) showed four different singlet methyl signals: τ 8.97, 5-CH_3 *cis* to phenyl; 8.22, 5-CH_3 *trans* to phenyl; 7.20, 2-CH_3; and 6.71, OCH_3. The difference in chemical shift between the two methyl groups at C-5, 0.75 ppm, is close to that observed for VI, VIII, and IX. The ring expansion of XI must proceed through cleavage of the 1,2 bond in order to produce structure XII. A logical, formal mechanistic sequence includes protonation of XI, solvolysis to produce the resonance-stabilized carbonium ion at C-2, followed by a Ritter-type reaction with acetonitrile to produce a carbonium–nitrilium ion, and attack of the 1-oxygen unshared pair of electrons on the new carbonium ion center to complete the formation of the five-membered ring in XII. The most logical reaction sequence to account for the ring expansion of the alkoxyaziridine X to IX with acetonitrile and acid would follow a similar route. The solvolysis of the protonated alkoxyaziridine X in acetone furnishes another example of ring expansion of this species, with 1,2-bond cleavage. An oxazolidinium perchlorate, $C_{16}H_{26}ClNO_6$, was obtained in 37% yield. This was hydrolyzable to α-aminoisobutyrophenone perchlorate (V) in 96% yield, thus indicating that the 1,3 bond in the original X had remained intact. The assigned structure, 5-isopropoxy-5-phenyl-2,2,4,4-tetramethyloxazolidinium perchlorate (XIII), was supported



XIII

further by the ultraviolet spectrum in acetonitrile, which showed the characteristics of a nonconjugated phenyl ring, and by the nmr spectrum, which accounted for all six methyl groups satisfactorily.

Returning to the ring expansion of 3,3-dimethyl-2-phenyl-1-azirine (I) with perchloric acid and acetonitrile, the problem of which bond of the three-membered ring is cleaved in the process is more subtle than in the case of X. The structure of the product VIII indicates that either N-1 or N-3 might have been the nitrogen originating from the acetonitrile. One logical solution to the problem was to label the nitrogen in the acetonitrile and to follow its path of incorporation in the final product. Accordingly, acetonitrile-^{15}N was prepared[18] from potassium cyanide-^{15}N and dimethyl sulfate and diluted with unlabeled acetonitrile. The abundance of ^{15}N in the acetonitrile was determined by hydrolysis of the nitrile with 70% aqueous perchloric acid, conversion of the ammonium perchlorate thus obtained into benzamide by a Schotten–Baumann reaction,[19] and subjection of the benzamide to mass spectrometry. Using the ratio of peak heights at *m/e* 122 and 121 [$(M + 1)^+$ and M^+] in the mass spectrum of the benzamide, the abundance of ^{15}N was calculated as 36%.

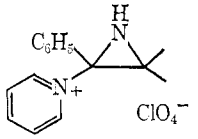
The acetonitrile of known label was combined with 3,3-dimethyl-2-phenyl-1-azirine and perchloric acid, and the product VI, labeled with ^{15}N, was hydrolyzed in neutral medium, yielding ammonium perchlorate (92%) and α-acetaminoisobutyrophenone (66%). In the α-acetaminoisobutyrophenone, the peaks at *m/e* 206 and 205 [$(M + 1)^+$ and M^+] could not be used for ^{15}N analysis, since the ratio of the peak heights in control unlabeled material was not in accord with the value calculated from the natural abundances of C, H, N, and O (see Experimental Section). However, two fragment ions could be used for our purposes. The fragment $C_5H_{10}NO^+$ (*m/e* 100), or $CH_3CO(CH_3)_2C{=}NH^+$, in the mass spectrum of unlabeled α-acetaminoisobutyrophenone did have the calculated ratio of peak heights for *m/e* 101 and 100. Also, the fragment $C_2H_4NO^+$ (*m/e* 58), or CH_3CONH^+, appeared not to be disturbed by other fragmentation patterns. The mass spectrum of the α-acetaminoisobutyrophenone obtained from the hydrolysis of labeled VI clearly showed the presence of ^{15}N by the peaks at 101 and 59. From the ratios of the peak heights 101/100 and 59/58, the abundance of ^{15}N was calculated to be 35%. The ammonium perchlorate obtained from the hydrolysis of labeled VI was converted into benzamide. In the mass spectrum of this benzamide sample the ratio of the peak heights 122/121 was identical, within the limits of accuracy, with the value observed for unlabeled benzamide as prepared from unlabeled ammonium perchlorate. This labeling experiment re-

(17) T. I. Temnikova and T. E. Zhesko, *Zh. Obshch. Khim.*, 33, 3436 (1965).

(18) In part adopted from E. V. Brown, E. Cerwonika, and R. C. Anderson, *J. Am. Chem. Soc.*, 73, 3735 (1951).

(19) In analogy with G. A. Swan and P. Kelly, *J. Chem. Soc.*, 416 (1954).

veals that the 1,3 bond of the azirine I has undergone cleavage during the formation of VI under the specified conditions, as in the case of the reaction of acetone. Therefore, the intermediate [A] in the reaction of 3,3-dimethyl-2-phenyl-1-azirine (I) and perchloric acid with acetonitrile is probably 5-phenyl-2,4,4-trimethyl-4H-isoimidazolium perchlorate (XIV; labeled form XIV′ shown). Numerous examples may be cited for the facile hydration of aromatic heterocyclic cations to form amidinium salts.[20-25] Ruled out by the direction of incorporation of the ^{15}N label in VI′ is any mechanism such as that illustrated in Figure 1, in which, following attack of acetonitrile at the 1,2 bond, the nitrile–nitrogen in the product becomes attached to the carbon bearing the phenyl group. Permitted by the labeling experiment is any mechanism incorporating 1,3-bond cleavage. One plausible mechanism involves protonation of the azirine, opening of the strained azirinium ring, attack of the nitrile at the developing tertiary carbonium ion to form a resonance-stabilized carbonium–nitrilium ion, and N–C bond formation between the imine nitrogen and the new carbonium ion center to complete the cyclization. The reaction path is similar to that suggested for acetone (see above), and the possibility of compressing the steps within this formal sequence is again recognized. An alternative possibility for the formation of the correctly labeled product VI′, involving initial attack of the azirine nitrogen on protonated acetonitrile, is considered less likely in the light of the behavior of perchloric acid with bases in anhydrous acetonitrile.[26-29] The azirine I was found to react with pyridine perchlorate in either pyridine or acetonitrile with formation of a stable adduct, 3,3-dimethyl-2-phenyl-2-N′-pyridiniumaziridine perchlorate (XV).



XV

The structure of a similar product, prepared from Neber's azirine[8] was proposed by Hatch and Cram.[30] Structure XV was established by analysis, nmr spectrum, and reversion to I on basification. The nmr spectrum (in acetone-d_6, TMS) showed singlet signals at τ values 8.87 (3 H), 8.55 (3 H), and 6.51 (1 H, N–H), the first two being indicative of the methyl groups influenced differently by the magnetic anisotropy of the two aromatic nuclei.

In summary, it can be said that in the reaction of 3,3-dimethyl-2-phenyl-1-azirine (I) and perchloric acid with methanol and with water, the major products arose

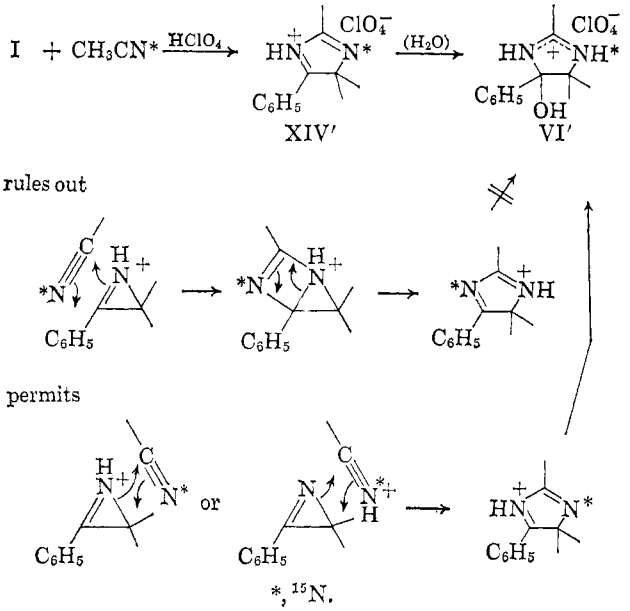


Figure 1. Nitrogen labeling for reaction path; * designates ^{15}N.

from initial nucleophilic addition to the 1,2 bond. In solvents such as acetone and actonitrile, the major products isolated from I and perchloric acid arose from 1,3-bond cleavage and ring enlargement at the cleavage site. These latter findings do not exclude the possibility of attack at the 1,2 bond, but products resulting from such addition were not isolated in this study. The ring expansion reactions presently recorded for azirines, alkoxyaziridines, and alkoxyoxiranes under acid conditions are suggestive of further applications in synthesis by mechanistic analogy.

Experimental Section[31]

3,3-Dimethyl-2-phenyl-1-azirine (I).[10] A mixture of 149 g (1.00 mole) of isobutyrophenone and 83 g (1.38 mole) of 1,1-dimethylhydrazine was heated under reflux for 3 days. The water layer was separated and extracted twice with 100 ml of ether. The combined organic layers were dried over anhydrous magnesium sulfate, and the solvent and excess hydrazine were removed on a rotary evaporator. The brown oil (isobutyrophenone dimethylhydrazone) was treated with 250 g of methyl iodide in 50 ml of absolute ethanol. The mixture was heated under gentle reflux for 6 hr. After cooling, ether was added, yielding 201 g of the crude isobutyrophenone dimethylhydrazone methiodide.[32] Recrystallization from ethanol–ethyl acetate gave 173 g (51%) of the pure methiodide, mp 138–140°.

A solution of 2.32 g (0.101 g-atom) of metallic sodium in 200 ml of isopropyl alcohol was added to a stirred solution of 34.2 g (0.103 mole) of the methiodide in 225 ml of isopropyl alcohol in 40 min at 35–40°. Stirring was continued for 45 min. The solvent and trimethylamine were removed on a rotary evaporator. The azirine I was separated from the sodium iodide by extraction with four 50-ml portions of dry ether. The ethereal solution was concentrated *in vacuo*, and the crude azirine was distilled under reduced pressure through a 10-cm Vigreux column, bp 93.5–95° (15 mm), yield 11.5 g (80%), $n^{22.5}D$ 1.5222, nmr signals (CCl_4) at τ values: 8.65 (singlet, 6 H), aromatic protons (5, 2.2–2.6 ppm).

Reaction of 3,3-Dimethyl-2-phenyl-1-azirine (I) with Acetone. a. Attempted Benzylation. To a solution of 2.08 g (10 mmoles) of

(20) A. Albert, Special Publication No. 3, The Chemical Society, London, 1955, p 138.
(21) A. R. Osborn, K. Schofield, and L. N. Short, *J. Chem. Soc.*, 4191 (1956).
(22) A. Albert, W. L. F. Armarego, and E. Spinner, *ibid.*, 2689 (1961).
(23) D. D. Perrin, *ibid.*, 645 (1962).
(24) A. Albert and W. L. F. Armarego, *Advan. Heterocyclic Chem.*, **4**, 1 (1965).
(25) D. D. Perrin, *ibid.*, **4**, 43 (1965).
(26) I. M. Kolthoff, S. Bruckenstein, and M. K. Chantooni, Jr., *J. Am. Chem. Soc.*, **83**, 3927 (1961).
(27) D. Bethell and J. D. Callister, *J. Chem. Soc.*, 3801, 3808 (1963).
(28) J. F. Coetzee and I. M. Kolthoff, *J. Am. Chem. Soc.*, **79**, 6110 (1957).
(29) J. F. Coetzee and G. R. Padmanabhan, *ibid.*, **87**, 5005 (1965).
(30) M. J. Hatch and D. J. Cram, *ibid.*, **75**, 38 (1953).

(31) All melting points were determined on a Kofler hot-stage microscope and are uncorrected. We are indebted to Mr. Josef Nemeth and his staff for microanalyses, to Mr. Dick H. Johnson and his co-workers for infrared and nmr spectra using a Perkin-Elmer Model 521 grating spectrophotometer and a Varian Associates Model A-60 spectrometer, and to Mr. Joseph Wrona for mass spectra using an Atlas Model CH4 spectrometer. Helpful exchanges of ideas with Dr. Erwin F. Muth during the preparation of this manuscript are gratefully acknowledged.
(32) P. A. S. Smith and E. E. Most, *J. Org. Chem.*, **22**, 358 (1957).

silver perchlorate in 20 ml of dry acetone was added 1.55 g (10.7 mmoles) of I. While stirring the solution, 1.71 g (10 mmoles) of benzyl bromide in 10 ml of acetone was introduced in 15 min at −5°. The reaction mixture was kept at 0° for 1.5 hr and then allowed to rise to room temperature. The precipitated silver bromide (1.75 g) was removed by filtration and washed with acetone. The combined filtrates were concentrated on a rotary evaporator, and the residual oil was dissolved in a small volume of acetone. After filtration of a small amount of silver bromide, addition of ether gave colorless crystals of 4-phenyl-2,2,5,5-tetramethyl-3-oxazolinium perchlorate (II), mp 257–258°, yield 1.19 g (39%). Recrystallization from methylene chloride–ether or ethylene chloride–ether gave analytically pure product, mp 271–272°, ν_{max}^{KBr} 2535 and 1642 cm^{-1}, λ_{max}^{EtOH} 241 mμ (ε 11,200); nmr τ values (DMSO-d_6, TMS): 8.49 (singlet, 6 H), 8.4 (singlet, 6 H), 2.0–2.6 (multiplet, 5 H), −0.06 (singlet, 1 H).

Anal. Calcd for $C_{13}H_{18}ClNO_6$: C, 51.40; H, 5.97; N, 4.61. Found: C, 51.35; H, 5.85; N, 4.45.

b. With 70% Aqueous Perchloric Acid. To a stirred solution of 725 mg (5.0 mmoles) of I in 80 ml of dry acetone was added a solution of 764 mg of 70% aqueous perchloric acid (5.2 mmoles) in 20 ml of acetone during 10 min at −30°. After 3 hr at −20° the solvent was removed on a rotary evaporator, leaving a brown oily residue. The oil was extracted with 2 ml of chloroform to remove by-product(s). The remaining solid was recrystallized from ethylene chloride–ether. α-Aminoisobutyrophenone perchlorate (98 mg) was filtered from the hot ethylene chloride solution. Compound II was obtained in 30% yield, 447 mg of intermediate, mp 265–267°.

c. With Silver Fluoroborate and *p*-Toluenesulfonic Acid. A solution of 1.854 g (10.8 mmoles) of anhydrous *p*-toluenesulfonic acid in 10 ml of methylene chloride was added in 50 min to a stirred solution of 1.450 g (10.0 mmoles) of I and 2.11 g (10.8 mmoles) of anhydrous silver fluoroborate in 100 ml of dry acetone at a temperature of −20°. Silver tosylate precipitated immediately. The mixture was allowed to rise to room temperature slowly and was left for 1.5 hr. Silver tosylate was removed by centrifugation. Solvents were removed on a rotary evaporator, giving a semisolid residue which upon trituration with methylene chloride and ether resulted in 1.22 g (42%) of a white solid (crude II as fluoroborate). Recrystallization from methylene chloride containing a little acetone gave upon addition of ether pure colorless crystals of II-fluoroborate, mp 208–209° dec, yield 30%, λ_{max}^{EtOH} 241 mμ (ε 11,000), ν_{max}^{KBr} 2535 and 1642 cm^{-1}; nmr τ values (acetone-d_6): 8.13 (singlet, 6 H), 7.99 (singlet, 6 H), 1.5–2.3 (multiplet, 5 H), and −1.13 (singlet, 1 H). Using anhydrous silver perchlorate instead of the fluoroborate pure II was obtained in 30% yield. When the reaction with the fluoroborate was carried out at −70° a crude yield of 55% was obtained (32% after recrystallization).

d. With *p*-Toluenesulfonic Acid. When anhydrous *p*-toluenesulfonic acid was added to a solution of I in acetone under conditions as described above, an oil resulted upon evaporation of solvent. The oil was dissolved in acetone and treated with 1 equiv of anhydrous silver perchlorate. After removal of silver tosylate and solvent, an oil was obtained which did not crystallize upon trituration with methylene chloride and ether. According to an infrared spectrum none of the II-perchlorate was formed. The oily product was not identified.

e. With Magnesium Perchlorate and *p*-Toluenesulfonic Acid. To a stirred solution of 1.450 g (10.0 mmoles) of I and 1.28 g (5.75 mmoles) of anhydrous magnesium perchlorate in 125 ml of dry acetone was added during 20 min a solution of 1.75 g (10.2 mmoles) of anhydrous *p*-toluenesulfonic acid in 8 ml of methylene chloride at −30°. A little magnesium tosylate had been suspended in the acetone solution to initiate its precipitation upon the addition of the *p*-toluenesulfonic acid. The mixture was stirred for 3 hr at −15° and then allowed to rise to room temperature. Magnesium tosylate was removed by centrifugation and washed with two portions of 1,2-dimethoxyethane. The combined solutions were concentrated on a rotary evaporator, resulting in a brown oil. Oily by-products were removed by extraction with 5 ml of chloroform, leaving a white solid which was recrystallized from ethylene chloride–ether, giving 912 mg (30%) of II, mp 268–270°.

f. With Acetone-d_6. The reaction was carried out as under e except that 25 ml of acetone-d_6 was used with 5 mmoles of I. A yield of 22% of pure II containing 6 D was obtained, ν_{max}^{KBr} 2550 and 1642 cm^{-1}; nmr τ values (DMSO-d_6, TMS): 8.39 (singlet, 6 H), 1.9–2.6 (multiplet, 5 H), −0.08 (singlet, 1 H). In a dilute solution in acetone-d_6 the high-field signal was observed at τ 8.05 while the unlabeled II had two high-field signals at τ 8.17 and 8.05.

g. The free base of II was prepared by treating 760 mg (2.5 mmoles) of II in 10 ml of water with 105 mg (2.6 mmoles) of sodium hydroxide in 2 ml of water. The free base was extracted with four 20-ml portions of methylene chloride. After drying over sodium sulfate and removal of the solvent, 498 mg (99%) of an oil was obtained. The oil was freed from solid impurities by distillation *in vacuo* employing a Hickman distillation apparatus, yielding 432 mg (85%) of the colorless free base, 4-phenyl-2,2,5,5-tetramethyl-3-oxazoline, bp *ca.* 65° (0.2 mm), $\nu_{max}^{CHCl_3}$ no O–H or N–H, but 1625, 1185, 1135, and 1000 cm^{-1}; nmr τ values (CCl_4): 8.47 (singlet, 6 H), 8.56 (singlet, 6 H), 2.0–2.8 (multiplet, 5 H).

Anal. Calcd for $C_{13}H_{17}NO$: C, 76.81; H, 8.43; N, 6.89. Found: C, 76.83; H, 8.57; N, 6.69.

h. Hydrolysis of II. A solution of 457 mg (1.50 mmoles) of II in 20 ml of water, to which four drops of 70% aqueous perchlorate acid had been added, was heated under reflux for 21 hr. Without neutralization the aqueous reaction mixture was extracted thoroughly with methylene chloride. The extracts were neutralized by washing with dilute sodium bicarbonate solution. After drying over sodium sulfate and removal of the solvent, slightly yellow benzoyl dimethyl carbinol (III) (237 mg, 96%) was obtained. The yellow color was removed by chromatography through a short silica column (elution with petroleum ether–ether, 1:1), $\nu_{max}^{CHCl_3}$ 3440 and 1668 cm^{-1}; nmr τ values: 8.52 (singlet, 6 H), 6.05 (singlet, 1 H), 1.9–2.8 (multiplet, 5 H). The spectra were identical with the corresponding spectra of the authentic ketol, prepared by hydrolysis of 1,2-epoxy-1-methoxy-2-methyl-1-phenylpropane. The water layer was concentrated *in vacuo*, yielding a solid residue which was washed with a little acetone and ether. Obtained was 167 mg (94%) of ammonium perchlorate, checked by comparison of the infrared spectrum with that of an authentic sample. Using a benzene cover layer during the hydrolysis of II under the conditions just described, the free base of II was isolated from the benzene layer in 72% yield after chromatography over silica. The aqueous layer gave 26% of ammonium perchlorate. Apparently the free base had been continuously extracted from the aqueous salt solution, preventing complete hydrolysis.

i. Hydrolysis of II obtained from acetone-d_6 (see under f), under the conditions described under h, gave 96% of ammonium perchlorate and 96% of benzoyl dimethyl carbinol; nmr τ values: 8.52 (singlet, 6 H), 6.05 (singlet, 1 H), 2.0–2.7 (multiplet, 5 H). The infrared spectrum was also identical with the one described under h.

j. With Ethyl Methyl Ketone. To a stirred solution of 1.450 g (10.0 mmoles) of I and 2.08 g (10.0 mmoles) of anhydrous silver perchlorate in 100 ml of ethyl methyl ketone was added a solution of 1.72 g (10.0 mmoles) of anhydrous *p*-toluenesulfonic acid in 15 ml of methylene chloride in 15 min at −35°. A little silver tosylate had been suspended in the reaction medium to initiate the precipitation. The mixture was left 1 hr at −30° and 2 hr at room temperature. Silver tosylate was removed by centrifugation. Upon removal of the solvents on a rotary evaporator a yellow oil was obtained which was extracted with hot methylene chloride. The residue after removal of the latter solvent gave an oil which crystallized partly upon standing. The crystals were separated from the oil and recrystallized from chloroform–ether, yielding 427 mg (15%) of 2-ethyl-4-phenyl-2,5,5-trimethyl-3-oxazolinium perchlorate, mp 184–185°, $\nu_{max}^{CHCl_3}$ 2740 and 1641 cm^{-1}; nmr τ values ($CDCl_3$): 8.93 (triplet, J = 7.5 cps, 3 H, CH_2CH_3), 8.21 (singlet, 3 H, CH_3 at C-2), 8.12 and 8.08 (both singlets, 6 H together, $(CH_3)_2$ at C-5), 7.88 (quartet, J = 7.5 cps, 2 H, CH_2CH_3), 2.3–2.6 (multiplet, 5 H, C_6H_5), and −2.20 (singlet, 1 H, N–H).

Anal. Calcd for $C_{14}H_{20}ClNO_5$: C, 52.91; H, 6.34; N, 4.41 Found: C, 52.98; H, 6.28; N, 4.18.

Methanolysis of I. To a stirred solution of 585 mg (4.03 mmoles) of the azirine I in 50 ml of absolute methanol was added slowly 586 mg (4.0 mmoles) of 70% aqueous perchloric acid at −30°. After allowing the temperature to rise to room temperature, an equal volume of benzene was added, and the solvents were removed on a rotary evaporator. The resulting colorless crystals of the dimethyl ketal of α-aminoisobutyrophenone perchlorate (IV) (1.22 g, 98.5%, mp 181–182.5°) were recrystallized from ethylene chloride, mp 182–182.5°, ν_{max}^{KBr} 3075 cm^{-1}, no carbonyl absorption between 1600 and 1800 cm^{-1}; nmr τ values (acetone-d_6): 8.65 (singlet, 6 H, $C(CH_3)_2$), 6.42 (singlet, 6 H, OCH_3), 2.43 (singlet, 5 H, C_6H_5); $\lambda_{max}^{CH_3CN}$ 250, 255.5, 261, 267.5, sh 275–280 mμ (ε 400, 405, 390, 220, and 25, respectively).

Anal. Calcd for $C_{12}H_{20}ClNO_6$: C, 46.53; H, 6.51; N, 4.52. Found: C, 46.40; H, 6.75; N, 4.43.

Hydrolysis of IV was accomplished by allowing a solution of 277 mg (0.0895 mmole) of the dimethyl ketal in 25 ml of water, to which

four drops of 70% aqueous perchloric acid was added, to stand at 25° for 3 days. Water was removed *in vacuo*, ethylene chloride being employed to remove the last traces. The crystalline residue was recrystallized from acetone–ether yielding 213 mg (91%) of pure α-aminoisobutyrophenone perchlorate (V), mp 255–256°, ν_{KBr}^{max} 3150 and 1680 cm^{-1}; nmr τ values (acetone-d_6): 7.95 (singlet, 6 H, $C(CH_3)_2$), 1.8–2.5 (multiplet, 5 H, C_6H_5), λ_{max}^{EtOH} 247 and 277 mμ (ε 9850 and 750).

Anal. Calcd for $C_{10}H_{14}ClNO_5$: C, 45.54; H, 5.36; N, 5.30. Found: C, 45.66; H, 5.40; N, 5.05.

Reactions of I with Nitriles. a. With Acetonitrile and Generated Perchloric Acid. To a stirred solution of 1.457 g (10.0 mmoles) of I and 1.27 g (5.7 mmoles) of anhydrous magnesium perchlorate in 100 ml of dry acetonitrile was added a solution of 1.96 g (1.14 mmoles) of *p*-toluenesulfonic acid in 30 ml of acetonitrile over 50 min at −20°. A little magnesium tosylate had been added to initiate its precipitation. Stirring was continued for 1 hr at room temperature. Magnesium tosylate was removed by centrifugation, and the solvent was removed from the remaining solution on a rotary evaporator. The oily residue crystallized from methylene chloride upon the addition of ether, yielding 2.32 g (77%) of the white crystalline product (VI), mp 134–137°, which could be recrystallized from 1,2-dimethoxyethane–methylene chloride–ether as 4-hydroxy-4-phenyl-2,5,5-trimethyl-2-imidazolinium perchlorate, final mp 158°, ν_{max}^{Nujol} 3450, 3280, 1618, 1595, 1580, and 1501 cm^{-1}; λ_{max}^{EtOH} 251, 256.5, 261, 263, 267, and 275–280 mμ (flat shoulder) (ε 190, 240, 200, 210, 140, and 50, respectively); nmr τ values (acetone-d_6): 9.11 (singlet, 3 H), 8.38 (singlet, 3 H), 7.48 (singlet, 3 H), 3.71 (singlet, 1 H), 2.80–2.30 (multiplet with sharp top at 2.51, 5 H), 0.42 (broad singlet, 1 H), and 0.20 (broad singlet, 1 H); (D_2O, TMS): 9.19 (singlet, 3 H), 8.44 (singlet, 3 H), 7.56 (singlet, 3 H), and 2.43 (broad singlet, 5 H). Employing a less dilute solution of I, a good yield of VI was also obtained.

Anal. Calcd for $C_{12}H_{17}ClN_2O_5$: C, 47.29; H, 5.62; N, 9.19. Found: C, 47.25; H, 5.66; N, 9.11.

When the aziridine in acetonitrile solution was treated with an equivalent of anhydrous *p*-toluenesulfonic acid (thus, no magnesium perchlorate present) removal of the solvent resulted in an oil. The latter was treated with 1 equiv of silver perchlorate in acetone. Impure VI was obtained in only very low yield.

b. The reaction in propionitrile was carried in the same manner as described under a. A yield of 66% of 5,5-dimethyl-2-ethyl-4-hydroxy-4-phenyl-2-imidazolinium perchlorate was obtained, mp 146–148°; nmr τ values (acetone-d_6): 9.13 (singlet, 3 H), 8.38 (singlet, 3 H), 8.60 (triplet, J = 7.5 cps, 3 H), 7.11, J = 7.6 cps, 2 H), 3.77 (singlet, 1 H), 2.49 (broad singlet, 5 H), 0.40 (broad singlet, 1 H), and 0.19 (broad singlet, 1 H); λ_{max}^{EtOH} 251, 256.5, 260.5, 262.5, 267, and flat shoulder at 275–280 mμ (ε 223, 284, 244, 260, 196, and 109, respectively).

Anal. Calcd for $C_{13}H_{19}ClN_2O_5$: C, 48.98; H, 6.01; N, 8.79. Found: C, 48.89; H, 6.02; N, 8.87.

c. With Acetonitrile and 70% Aqueous Perchloric Acid. A solution of 340 mg (2.3 mmoles) of 70% aqueous perchloric acid in 10 ml of acetonitrile containing 1.3 g of anhydrous magnesium perchlorate was introduced to a stirred solution of 298 mg (2.06 mmoles) of I in 30 ml of acetonitrile in 30 min at −30°. The mixture was left at −25° for 0.5 hr and for 2 hr at room temperature. After removal of the solvent on a rotary evaporator, the solid residue was extracted twice with 50 ml of ether in order to remove magnesium perchlorate. The remaining solid was dissolved in hot acetone–methylene chloride (1:5) and ether was added. Compound VI was obtained in a yield of 276 mg (44%). The infrared spectrum did not show the presence of the possible contaminant V. When the reaction was carried out in the absence of magnesium perchlorate, the crystalline material obtained (68%) was contaminated with α-aminoisobutyrophenone perchlorate (V), which could be removed by several recrystallizations from methyl acetate–ether.

d. With Acetonitrile and 2,4,6-Trinitrobenzenesulfonic Acid. To a solution of 773 mg (5.05 mmoles) of I in 20 ml of anhydrous acetonitrile was added a solution of 1.48 g (5.05 mmoles) of 2,4,6-trinitrobenzenesulfonic acid in 15 ml of acetonitrile during 25 min at −25° with efficient stirring. The reaction mixture was stirred 1 hr at −20° and was allowed to come to room temperature. Solvent was removed to half-volume in a rotary evaporator, and one volume of chloroform was added. Crystallization was completed by the addition of ether, yielding 1.42 g (57%) of 4-hydroxy-4-phenyl-2,5,5-trimethyl-2-imidazolinium 2,4,6-trinitrobenzenesulfonate, recrystallized from acetonitrile–ether, mp 176–179°; ν_{max}^{Nujol} 3360, 3240, 1625, and 1580 cm^{-1}; nmr τ values (DMSO-d_6): 9.31 (singlet, 3 H), 8.57 (singlet, 3 H), 7.66 (singlet, 3 H), 6.55 (singlet, 1 H), 2.53 (singlet, 5H), 1.12 (singlet, 2 H), −0.53 (singlet, 1 H), and −0.81 (singlet, 1 H).

Anal. Calcd for $C_{18}H_{19}N_5O_{10}S$: C, 43.46; H, 3.85; N, 14.08. Found: C, 43.52; H, 3.87; N, 13.90.

Hydrolysis of 4-Hydroxy-4-phenyl-2,5,5-trimethyl-2-imidazolinium Perchlorate (VI). a. In Acid Medium. A solution of 310 mg (1.02 mmoles) of the perchlorate VI in 25 ml of water containing 190 mg (1.3 mmoles) of 70% aqueous perchloric acid was heated under gentle reflux for 17 hr. The solvent was removed *in vacuo* leaving 313 mg of a solid which was extracted with acetone–methylene chloride (1:10). Upon addition of ether to the extract 194 mg (73%) of α-aminoisobutyrophenone perchlorate (V) was obtained, identified by ultraviolet, nmr, and infrared spectra, and by mixture melting point. The insoluble material, 91 mg (76%), was identified as ammonium perchlorate.

b. In Neutral Medium. A solution of 459 mg (1.50 mmoles) of VI in 15 ml of water was heated under gentle reflux for 2 hr. Water was removed *in vacuo*, and the residue was extracted with methylene chloride, leaving as a residue 162 mg (92%) of ammonium perchlorate. Upon removal of the solvent from the extract, 286 mg of oil was obtained, which partially crystallized. Upon sublimation at 60° (0.1 mm) a white solid was obtained which was identified as α-acetaminoisobutyrophenone (VII), mp 120–121°, yield 198 mg (64%); ν_{max}^{KBr} 3280, 1680, and 1640 cm^{-1}; $\nu_{max}^{CHCl_3}$ 3420, 3270, and 1690–1640 (br) cm^{-1}; nmr τ values ($CDCl_3$): 8.42 (singlet 6 H, $(CH_3)_2$), 8.24 (singlet, 3 H, CH_3CO), 2.33 (singlet, 1 H, N–H), 1.85–2.75 (multiplet, 5 H, C_6H_5; λ_{max}^{EtOH} 242 mμ (ε 10,080) and 278 mμ (sh) (690).

Anal. Calcd for $C_{12}H_{15}NO_2$: C, 70.22; H, 7.37; N, 6.82. Found: C, 69.96; H, 7.31; N, 6.57.

Hydrogenation of VI. A solution of 309 mg (1.02 mmoles) of VI in 30 ml of pure acetone with 150 mg of platinum oxide was hydrogenated at 46 psi for 8 hr. The filtered acetone solution was concentrated *in vacuo*, and the residual oil was triturated with methylene chloride and ether yielding 261 mg (84%) of 4-cyclohexyl-4-hydroxy-2,5,5-trimethyl-2-imidazolinium perchlorate, recrystallized from methylene chloride–ether, mp 150–152°; ν_{max}^{Nujol} 3470, 3280, 1623, and 1590 cm^{-1}; nmr τ values (acetone-d_6): 8.0–9.0 (unresolved multiplet), 7.61 (singlet), no aromatic protons; λ_{max}^{EtOH} 273 mμ (ε 98).

Anal. Calcd for $C_{12}H_{23}ClN_2O_5$: C, 46.37; H, 7.46; N, 9.01. Found: C, 46.40; H, 7.60; N, 8.53.

Alcoholysis of VI. a. With Ethanol. A solution of 310 mg (1.02 mmoles) of VI in 25 ml of absolute ethanol was refluxed for 5 hr. Upon removal of the ethanol *in vacuo* a semisolid residue remained, which gave, after recrystallization from methylene chloride–ether, 351 mg (93%) of 4-ethoxy-4-phenyl-2,5,5-trimethyl-2-imidazolinium perchlorate (VIII), mp 141–142°; $\nu_{max}^{CHCl_3}$ 3210, 1623, and 1575 cm^{-1}; nmr τ values ($CDCl_3$): 9.25 (singlet, 3 H), 8.88 (triplet, J = 7 cps, 3H), 8.45 (singlet, 3 H), 7.52 (singlet, 3 H), 6.74 (center of two very close overlapping quartets, $J \cong 8$ cps, 2 H), 2.60 (singlet, 5 H, C_6H_5), 0.97 (singlet, 1 H), and 0.50 (singlet, 1 H); λ_{max}^{EtOH} 252, 256.5, 261, 263, and 267 mμ (ε 185, 240, 210, 202, and 140, respectively).

Anal. Calcd for $C_{14}H_{21}ClN_2O_5$: C, 50.52; H, 6.36; N, 8.42. Found: C, 50.39; H, 6.22; N, 8.08.

Prolonged refluxing of VI in ethanol (600 hr) did not effect any further change, and the product VIII was isolated in 87% yield.

b. With Isopropyl Alcohol. A solution of 307 mg (1.01 mmoles) of VI in 30 ml of dry isopropyl alcohol was refluxed for 8 hr. After removal of the solvent *in vacuo* a semisolid residue remained. Recrystallization from methylene chloride–ether–pentane gave 301 mg (87%) of 4-isopropoxy-4-phenyl-2,5,5-trimethyl-2-imidazolinium perchlorate (IX). A small amount of starting material (38 mg) was separated by dissolving the product in chloroform. Addition of ether to the filtered solution gave 72% of pure IX, mp 141–142°, identical with the compound obtained from 3,3-dimethyl-2-isopropoxy-2-phenylaziridine (X).

3,3-Dimethyl-2-isopropoxy-2-phenylaziridine (X).[10] A solution of 10.3 g (71 mmoles) of I in 80 ml of dry isopropyl alcohol, in which 146 mg of metallic sodium was dissolved, was refluxed for 5 hr. Benzoic acid (780 mg) was added, and sodium benzoate was removed by filtration. After removal of the solvent the residual oil was taken up in pentane and extracted with three small portions of water. The pentane solution was dried over sodium sulfate and then concentrated *in vacuo*. Distillation of the residual liquid gave 10.4 g (72%) of X, bp 104–105° (9 mm), $n^{24.5}D$ 1.4939; nmr τ values (CCl_4): 9.24 (singlet, 3 H), 9.08 (doublet, J = 7.0 cps, 3 H),

8.90 (doublet, J = 7.0 cps, 3 H), 8.58 (singlet, 3 H), 6.25 (septuplet, J = 7.0 cps, 1 H), 2.9–2.4 (multiplet, 5 H, C_6H_5).

Reaction of X with Nitriles. a. With Acetonitrile. To a solution of 575 mg (2.68 mmoles) of anhydrous magnesium perchlorate in 50 ml of dry acetonitrile were added 1.029 g (5.00 mmoles) of X and a small amount of magnesium tosylate. While stirring, a solution of 873 mg (5.08 mmoles) of anhydrous *p*-toluenesulfonic acid in 8 ml of acetonitrile was added in 45 min at −40°. Stirring was continued for 1 hr at −30° and for 1 hr at room temperature. The precipitated magnesium tosylate was removed by centrifugation. The oily residue obtained upon removal of the solvent on a rotary evaporator crystallized partly upon trituration with methylene chloride. The crystals were separated and identified as α-aminoisobutyrophenone perchlorate (V) by infrared and nmr spectra, yield 319 mg (24%). To the methylene chloride extract ether and a little pentane were added, yielding 992 mg (57%) of 4-isopropoxy-4-phenyl-2,5,5-trimethyl-2-imidazolinium perchlorate (IX). The product was recrystallized from methylene chloride–ether–pentane, mp 141–142°; $\nu_{max}^{CHCl_3}$ 3210, 1624, and 1573 cm^{-1}; nmr τ values ($CDCl_3$): 9.26 (singlet, 3 H), 9.01 (doublet, J = 6 cps, 3 H), 8.89 (doublet, J = 6 cps, 3 H), 8.41 (singlet, 3 H), 7.51 (singlet, 3 H), 6.3 (unresolved multiplet, 1 H), 2.55, (singlet, 5 H), 1.00 (singlet, 1 H) and 0.52 (singlet, 1 H); λ_{max}^{EtOH} 251, 256.5, 261, 263, and 267 mμ (ε 207, 249, 220, 208, and 139, respectively).

Anal. Calcd for $C_{15}H_{23}ClN_2O_5$: C, 51.95; H, 6.68; N, 8.08. Found: C, 52.14; H, 6.71; N, 7.72.

The product obtained by this ring enlargement reaction was identical with the compound obtained by treatment of VI with isopropyl alcohol (see above).

b. With propionitrile as the solvent the reaction with X was carried out in the same way except that half the amount of solvent was used. Hydrolysis of product V was obtained in 22% yield and 5,5-dimethyl-2-ethyl-4-isopropoxy-4-phenyl-2-imidazolinium perchlorate in 55% yield, mp 142–143°; $\nu_{max}^{CHCl_3}$ 3210, 1620, and 1570 cm^{-1}; nmr τ values ($CDCl_3$): 9.28 (singlet, 3 H, CH_3 at C-5 *cis* to phenyl), 9.01 (doublet, J = 6.0 cps, 3 H, $OCH(CH_3)_2$), 8.86 (doublet, J = 6.0 cps, 3 H, $OCH(CH_3)_2$), 8.62 (triplet, J = 8.0 cps, 3 H, CH_2CH_3), 8.40 (singlet, 3 H, CH_3 at C-5 *trans* to phenyl), 7.19 (quartet, J = 7.5 cps, 2 H, CH_2CH_3), 6.31 (septulet, J = 6.0 cps, 1 H, $OCH(CH_3)_2$), 2.56 (singlet, 5 H, C_6H_5), 1.00 (singlet, 1 H, N–H at position 3), and 0.52 (singlet, 1 H, N–H at position 1).

Anal. Calcd for $C_{16}H_{25}ClN_2O_5$: C, 53.25; H, 6.98; N, 7.76. Found: C, 53.40; H, 6.99; N, 7.76.

c. Conversion of IX to VIII. The product obtained under a was converted into VIII by refluxing 347 mg (1.00 mmole) in 50 ml of absolute ethanol for 24 hr. A trace of concentrated perchloric acid had been added as catalyst. After removal of the solvent a solid residue was obtained, which was dissolved in 5 ml of chloroform. To the filtered solution ether was added, yielding 308 mg (93%) of the product VIII, as secured by analytical, spectral, and melting point criteria.

Preparation of 4-Methoxy-4-phenyl-2,5,5-trimethyl-2-oxazolinium Perchlorate (XII) by Ring Enlargement of XI. 3,3-Dimethyl-2-methoxy-2-phenyloxirane (XI) was prepared from α-bromoisobutyrophenone and sodium methoxide in methanol according to the method of Stevens and Farkas;[12a] nmr τ values (CCl_4): 9.05 (singlet, 3 H, CH_3 at C-3 *cis* to phenyl), 8.52 (singlet, 3 H, CH_3 at C-3 *trans* to phenyl), 6.87 (singlet, 3 H, OCH_3), 2.5–2.8 (multiplet, 5 H, C_6H_5). To a solution of 1.135 g (5.09 mmoles) of anhydrous magnesium perchlorate in 40 ml of acetonitrile was added 1.785 g (10.0 mmoles) of the epoxy ether XI, and then a solution of 1.732 g (10.0 mmoles) of anhydrous *p*-toluenesulfonic acid in 10 ml of acetonitrile was introduced during 40 min at −20° with efficient stirring. Stirring was continued for 2 hr at −15° and for 2 hr at room temperature. The precipitated magnesium tosylate was removed by centrifugation and the solution was concentrated *in vacuo*. The solid residue was recrystallized from methylene chloride–ether or chloroform–ether, mp 132–137° dec, yield 2.398 g (75%) of XII; $\nu_{max}^{CHCl_3}$ 2650 and 1635 cm^{-1}; nmr τ values ($CDCl_3$): 8.97, 8.22, 7.20, 6.71 (all singlets representing three protons), 2.51 (singlet, 5 H, C_6H_5), and −2.2 (broad singlet, 1 H); $\lambda_{max}^{CH_3CN}$ 252, 257, 262, and 268 mμ (ε 266, 326, 313, and 206, respectively).

Anal. Calcd for $C_{18}H_{18}ClNO_6$: C, 48.83; H, 5.67; N, 4.38. Found: C, 48.56; H, 5.72; N, 4.22.

Hydrolysis of XII was accomplished by refluxing 640 mg (2.0 mmoles) of XII in 10 ml of water for 2 hr. After cooling, the aqueous solution was extracted with four 20-ml portions of methylene chloride. The combined extracts were dried over sodium sulfate and concentrated *in vacuo*, yielding 392 mg (95%) of benzoyl dimethyl carbinol acetate. Solid impurities were removed by distillation under reduced pressure employing a Hickman distillation apparatus. At bp 75° (0.2 mm) a colorless oil came over which solidified on the cold finger, mp 56–59°; $\nu_{max}^{CHCl_3}$ 1733 and 1675 cm^{-1}, no O–H; nmr τ values (CCl_4): 8.36 (singlet, 6 H, $C(CH_3)_2$), 8.16 (singlet, 3 H, CH_3CO), 1.9–2.7 (multiplet, 5 H, C_6H_5); λ_{max}^{EtOH} 243 and *ca.* 280 (sh) mμ.

Anal. Calcd for $C_{12}H_{14}O_3$: C, 69.88; H, 6.84. Found: C, 69.80; H, 6.80.

The aqueous layer remaining after the extraction was concentrated at reduced pressure, yielding ammonium perchlorate, 222 mg (95%).

Reaction of X with Acetone. To a solution of 580 mg (2.60 mmoles) of anhydrous magnesium perchlorate in 60 ml of dry, freshly distilled acetone was added 1.033 g (5.00 mmoles) of X, and a little magnesium tosylate was suspended. A solution of 8.82 mg (8.14 mmoles) of anhydrous *p*-toluenesulfonic acid in 3 ml of methylene chloride was introduced in 20 min at −35° with efficient stirring. After allowing the temperature of the reaction mixture to rise to room temperature, magnesium tosylate was removed by centrifugation and washed with 1,2-dimethyoxyethane. The combined solutions were concentrated on a rotary evaporator, yielding a solid residue. The latter was extracted with 15 ml of chloroform, leaving 525 mg (40%) of α-aminoisobutyrophenone perchlorate (V) undissolved. To the extract ether was added, giving 682 mg (37%) of 5-isopropoxy-5-phenyl-2,2,4,4-tetramethyloxazolidinium perchlorate (XIII). Solution in methylene chloride, filtration, and precipitation with ether and pentane were twice repeated, giving XIII of mp 161–167°, nmr τ values ($CDCl_3$): 8.90 (singlet, 3 H) 8.92 (doublet, J = 6.0 cps, 3 H), 8.82 (doublet, J = 6.0 cps, 3 H), 8.21 (singlet, 3 H), 8.09 (singlet, 3 H), 7.99 (singlet, 3 H), 6.12 (septuplet, J = 6.0 cps, 1 H), 2.52 (singlet, 5 H, C_6H_5). The spectrum in acetone-d_6 showed the same peaks except that the chemical shift between the two doublets of the methyl groups in the isopropoxy group was greater: 8.95 (doublet, J = 6.0 cps), 8.89 (singlet), 8.81 (doublet, J = 6.0 cps), 8.22 (singlet), 8.08 (singlet), 8.00 (singlet), 6.10 (septuplet); $\lambda_{max}^{CH_3CN}$ 251, 256, 262, and 268 mμ (ε 710, 665, 460, and 230, respectively). Upon standing of the acetonitrile solution, the extinction increased rather rapidly due to hydrolysis by traces of water.

Anal. Calcd for $C_{16}H_{26}ClNO_6$: C, 52.82; H, 7.20; N, 3.85 Found: C, 52.86; H, 7.04; N, 4.15.

Hydrolysis of XIII. A solution of 124 mg (0.34 mmole) of XIII in 8 ml of water was refluxed for 30 min. Water was removed *in vacuo*, and the white residual solid was recrystallized from acetone–ether, yielding 86 mg (96%) of α-aminoisobutyrophenone perchlorate (V).

Preparation[18] of Acetonitrile-^{15}N. Potassium cyanide-^{15}N (3.41 g of 90% KCN containing 97% of ^{15}N)[33] was dissolved in 3 ml of water. Under efficient stirring and cooling 6.04 g (48 mmoles) of freshly distilled dimethyl sulfate was introduced in 30 min at −5°. The reaction flask was equipped with a Dry Ice condenser to prevent any loss by volatilization. After the addition was concluded stirring was continued for 30 min. About 4 ml of crude acetonitrile was collected upon distillation of the aqueous mixture over the boiling point range 70–100°. After addition of 1.5 ml of unlabeled acetonitrile to the residue the fraction of 76–100° was again collected. The distillates were extracted with four 2-ml portions of methylene chloride. The combined extracts were dried over sodium sulfate and molecular sieves (Type Linde 4A) and subjected to distillation, employing a 10-cm Vigreux column. Three fractions were collected: bp 38–42 (methylene chloride), 42–81, and 81–83° (acetonitrile). The middle fraction was redistilled after 1.5 ml of unlabeled acetonitrile had been added. Again the fraction 81–83° was collected, giving 3.17 g of acetonitrile in all. The amount of excess ^{15}N was determined[34] by converting the product obtained into benzamide. To 130 mg (3.1 mmoles) of the labeled acetonitrile was added 600 mg of 70% aqueous perchloric acid. The solution was heated very slowly until the vigorous hydrolysis took place. After addition of a little water the mixture was refluxed for 24 hr to complete the hydrolysis. Upon cooling, crystals of ammonium perchlorate separated, and addition of acetone and a little ether completed the crystallization, yield 244 mg (68%). The conversion into benzamide was accomplished as follows.[19] A solution of 118 mg of the ammonium perchlorate in 3 ml of water was cooled in ice, and 85 mg of sodium hydroxide in 1 ml of water added. The ammonia solution was shaken with a solution of 151 mg of benzoyl

(33) Purchased from Isomet Corp., Palisades Park, N. J.

(34) The $(M - 2)^+$ and $(M - 1)^+$ peaks (*m/e* 39 and 40) in the mass spectrum of CH_3CN were too intense to permit ^{15}N analyses from *m/e* 41 and 42.

chloride in 8 ml of alcohol-free chloroform for 1 hr. The chloroform layer was separated, and the aqueous layer was extracted with four 3-ml portions of chloroform. The combined extracts were dried over sodium sulfate and concentrated *in vacuo*. The remaining crystalline benzamide was washed several times with pentane to remove traces of benzoyl chloride and then with a small volume of ether, yield 93 mg (76%) of benzamide labeled with ^{15}N, mp 128–129°.

In the mass spectrum the ratio of the intensities of the peaks at *m/e* 122 $(M + 1)^+$ and 121 $(M)^+$ was 0.644 at 70 ev (averaged over three scannings) and 0.622 at 13 ev (averaged over five scannings). From this ratio the abundance of ^{15}N was calculated[35,36] to be 36.2% (from the spectrum at 70 ev) and 36.9% (from the spectrum at 13 ev).

Reaction of I in Acetonitrile-^{15}N. To the labeled acetonitrile (3.2 g) was added 292 mg (2.00 mmoles) of I, 268 mg (1.20 mmoles) of anhydrous magnesium perchlorate, and a little magnesium tosylate. To the stirred reaction mixture was added 355 mg (2.06 mmoles) of anhydrous *p*-toluenesulfonic acid dissolved in 0.5 ml of methylene chloride, by means of a syringe, in 10 min at −30°. The gelatinous mixture was left overnight in a refrigerator. After addition of 5 ml of methylene chloride the precipitate was centrifuged and washed with 2 ml of methylene chloride. The solution was concentrated by distillation *in vacuo*, yielding a solid residue. From the distillate the acetonitrile was recovered by fractional distillation. The precipitate was extracted once with 10 ml of 1,2-dimethoxyethane. This extract was combined with the solid residue and concentrated *in vacuo* leaving the crude product, which was recrystallized from 1,2-dimethoxyethane–methylene chloride (1:5 and ether, yield 327 mg (55%) of the labeled product VI.

Hydrolysis of the Labeled Product VI. A solution of 312 mg of the labeled product VI in 10 ml of water was refluxed for 2.5 hr. Water was removed at reduced pressure leaving an oily residue, which was treated with methylene chloride. Ammonium perchlorate (108 mg, 92%) was collected by filtration. After removal of the solvent, the methylene chloride extract yielded an oil which gave upon sublimation 138 mg (66%) of α-acetaminoisobutyrophenone (VII'). The ratio of peak heights at *m/e* 206 and 205 in the mass spectrum of *unlabeled* VII was 0.674 at 70 ev and 0.445 at 15 ev, for the peaks at 101 and 100 $(C_5H_{10}NO)^+$ the ratio was 0.057 (70 ev), and for the peaks at 59 and 58 $(C_2H_4NO)^+$ it was 0.0358. As calculated[35,36] from the natural abundances of C, H, N, and O, the ratio should read: 0.1367, 0.0598, and 0.0265. The product VII' obtained from labeled VI showed the following ratio of peak heights: M^+ (206/205), 0.703 at 70 ev and 0.674 at 15 ev; fragment $C_5H_{10}NO^+$ (101/100), 0.595 (70 ev); and fragment $C_2H_4NO^+$ (59/58), 0.566 (70 ev). From the ratios found for the two fragments the abundance of ^{15}N was calculated to amount to 35.0% (fragment $C_5H_{10}NO)^+$ and 35.3% (fragment $C_2H_4NO)^+$. The ammonium perchlorate obtained from the hydrolysis was converted into benzamide by means of the Schotten–Baumann reaction described above, in a yield of 80%. The mass spectrum of this sample of benzamide showed for *m/e* 122 $[(M + 1)^+]$ and 121 (M^+) a ratio of peak heights of 0.092 at 70 ev and 0.096 at 12.5 ev. The mass spectrum of unlabeled benzamide prepared from ammonium perchlorate by the Schotten–Baumann reaction showed for $(M + 1)^+/M^+$ 0.090 at 70 ev and 0.087 at 12.5 ev. As calculated from the natural abundances this ratio should read 0.08097.[36]

Reaction of I with Pyridinium Perchlorate. **a.** To a solution of 1.55 g (8.65 mmoles) of pyridinium perchlorate in 15 ml of pure pyridine was added 1.25 g (8.62 mmoles) of I in 5 min at 0°. The mixture was left in the refrigerator for 14 days. Ether was added and white crystals separated, mp 130–132°, yield 2.65 g (95%). The 3,3-dimethyl-2-phenyl-2-N'-pyridinium aziridine perchlorate (XV) was recrystallized from acetone–ether, mp 131–132°; ν_{max}^{Nujol} 3270 and 1625 cm^{-1}; nmr τ values (acetone-d_6): 8.87 (singlet, 3 H), 8.55 (singlet, 3 H), 6.51 (singlet, 1 H), 2.7–0.3 (multiplet of nine aromatic protons).

Anal. Calcd for $C_{15}H_{17}ClN_2O_4$: C, 55.47; H, 5.27; N, 8.63. Found: C, 55.99; H, 5.43; N, 8.45.

b. To a solution of 364 mg (2.02 mmoles) of pyridinium perchlorate in 4 ml of acetonitrile was added 291 mg (1.00 mmole) of I dissolved in 2 ml of acetonitrile during 5 min at 0°. The mixture was left in the refrigerator for 4 days. The slightly yellow reaction mixture was concentrated *in vacuo* to half-volume, and ether was added. 3,3-Dimethyl-2-phenyl-2-N'-pyridinium aziridine perchlorate was obtained, yield 524 mg (81%). Upon refluxing of the product in acetonitrile solution for 24 hr, pyridinium perchlorate was formed in 89% yield.

c. No reaction occurred with I and trimethylamine perchlorate in acetonitrile solution at room temperature during 2 months.

(35) The formula for the abundance of $(M + 1)^+$ was employed; the values are not corrected for the natural abundance of ^{15}N.

(36) J. H. Beynon, "Mass Spectrometry and its Applications to Organic Chemistry," Elsevier Publishing Co., Amsterdam, 1960.

Addition of Isopropyllithium in Diethyl Ether to α-Substituted Styrenes. Quantitative Evidence on the Stability of Cyclopropylcarbinyllithium Species

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Abstract: The relative rates of addition of isopropyllithium in diethyl ether at −45° to a series of α-substituted styrenes in which the substituent was ethyl (**1a**), isopropyl (**1b**), 3-pentyl (**1c**), cyclopropyl (**1d**), and *trans*-2-*cis*-3-dimethylcyclopropyl (**1e**) were 28.0, 1.0, 0.6, 310, and 115, respectively. The product of addition of isopropyllithium to **1d** after hydrolysis was 4-phenyl-2-methyl-*cis*-4-heptene (**6**) while addition to **1e** followed by hydrolysis produced a mixture of olefin **8** and cyclopropanes **9, 10,** and **11.** It is concluded that the cyclopropylcarbinyl anion must be stabilized at least in part by conjugative interaction with the cyclopropane ring.

Until now no quantitative evidence has been reported which would allow anything better than a crude comparison of the cyclopropylcarbinyl anion stability with that of structurally related species.

The successful preparation by Lansbury and coworkers[2] of a relatively stable cyclopropylcarbinyl-

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(2) (a) P. T. Lansbury, V. A. Pattison, W. A. Clement, and J. D. Sidler, *J. Am. Chem. Soc.*, **86,** 2247 (1964); (b) P. T. Lansbury and V. A. Pattison, *ibid.*, **85,** 1886 (1963).