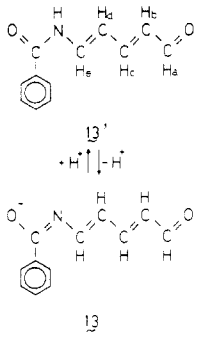
Scheme II



extent of the conjugation. It is of interest here to point out that the λ_{max} values of **13** (423 nm) and **12** (420 nm) agree well with that of **11'** (421 nm), manifesting the mutual relevancy of molecular structures determined in this work.

Conclusion

N^2-[(1*E*,3*E*)-1,3-Butadienyl]-N^1-1,3-butadienylbenzamidine (**11'**) and *N*-[(1*E*,3*E*)-4-methanoyl-1,3-butadienyl]benzenecarboxamide (**13'**), but not **2**, have been found to be responsible for the red color in the Fujiwara reaction when benzotrichloride was used as a chromogenic reagent. In alkaline media, these compounds take the anionic forms **11** and **13** as a result of deprotonation of the NH group. Owing to these extended conjugated systems, they develop an intense red and yellow color, respectively. These compounds appear to be formed by the hydrolysis of a dipyridinium cation which results in ring breakage of the pyridine rings.

Acknowledgment. We thank professors K. Machida, T. Nakagawa, and T. Ibuka of Kyoto University for their helpful advice. Thanks are also due to Dr. M. Sano and the staff of Daiichi Seiyaku Co. Ltd. for the measurements of FD mass spectra.

Registry No. 11', 77965-69-6; 13', 77965-70-9; benzotrichloride, 98-07-7.

Reactivity of 2-Aminothiazole toward 2,4-Dinitrofluorobenzene. Products and Structures

Luciano Forlani*

Istituto di Chimica Organica, Bologna, Italy

Paolo De Maria

Istituto di Chimica degli Intermedi, Bologna, Italy

Elisabetta Foresti and Gabriele Pradella

Istituto di Mineralogia e Petrografia, Bologna, Italy

Received December 30, 1980

2-Aminothiazole and 4-methyl-2-aminothiazole act as bident nucleophiles toward 2,4-dinitrofluorobenzene (DNFB) in dimethyl sulfoxide. Product structures have been ascertained by ^{1}H NMR spectroscopy as well as by X-ray analysis. In the absence of steric hindrance, the "aza" nitrogen is a more effective nucleophile site than the exocyclic "amino" nitrogen of the 2-aminothiazoles.

2-Aminothiazole reacts as a nucleophile with either of its nitrogen atoms, the exocyclic nitrogen or the endocyclic nitrogen, depending upon the electrophilic center and the experimental conditions. For example, with alkyl halides,[1] in the absence of strong bases, the endocyclic nitrogen is the main nucleophile, while with acyl[2] and sulfonyl[3] halides the exocyclic nitrogen is the main nucleophile. In order to collect further information on this behavior and to test an example of nucleophilic attack on an aromatic sp^2 carbon, we have investigated the reactions of 2-aminothiazole, 4-methyl-2-aminothiazole and 2-(*sec*-butylamino)thiazole with 2,4-dinitrofluorobenzene (DNFB) in dimethyl sulfoxide. The structures of reaction products have been assigned by ^{1}H NMR spectroscopy and X-ray analysis.

(1) J. V. Metzger, Ed., "Thiazole and Its Derivatives", Vol. 2, Wiley, New York, 1979.

(2) V. V. Kuskkin and I. Postowski, *Dokl. Akad. Nauk. SSSR*, **93**, 63 (1953); D. Suciu, *Stud. Univ. Babes-Bolyai, [Ser.] Chem.*, **15**, 123 (1970); P. M. Kochergine, *Zh. Obshh. Khim.*, **26**, 2897 (1957); M. Sélim, G. Martin, and M. Sélim, *Bull. Soc. Chim. Fr.*, 3268 (1968).

(3) J. Druey, *Helv. Chim. Acta*, **24**, 226E, (1941); J. P. English, J. H. Clark, J. W. Clapp, D. Seeger, R. H. Ebel, and W. Fosbinder, *J. Am. Chem. Soc.*, **61**, 2032, (1939); J. M. Sprangue, R. M. Lincoln, and C. Ziegler, *ibid.*, **68**, 266, (1946); D. H. Dorn, G. Hilgetag, and A. Rieche, *Angew. Chem.*, **73**, 560, (1961).

Results and Discussion

The reaction between 2-aminothiazole and DNFB, in equimolecular amounts or with a deficiency of DNFB, is complete in about 48 h in dimethyl sulfoxide at 25 °C. The major product of this reaction is an imino derivative, as ascertained by its ^{1}H NMR spectrum (see Table I[17]). In fact, the signals of the protons of the thiazole ring are in the same field range (H_4) or shifted to higher field (H_5)

0022-3263/81/1946-3178$01.25/0

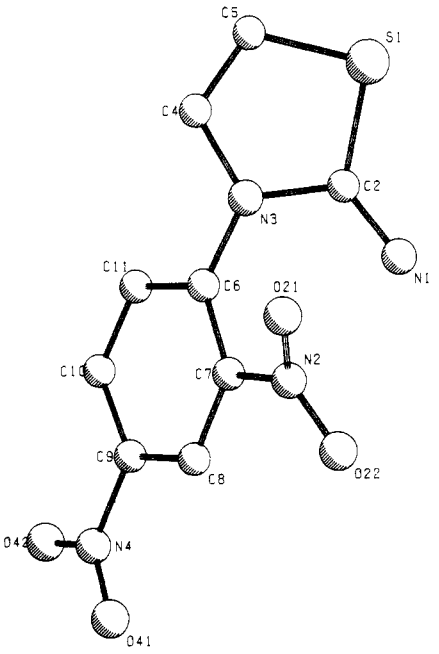
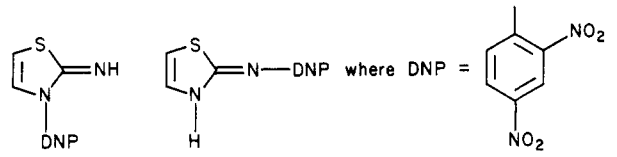


Figure 1. Perspective drawing and numbering scheme of compound I. Hydrogens have been omitted for clarity.

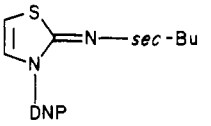
with respect to the signals of the corresponding protons of 2-aminothiazole itself (δ_{H_4} 7.08 and δ_{H_5} 6.66 in Me_2SO-d_6) in spite of the electron-withdrawing effect of the dinitrophenyl group.[4] Two possible imino derivatives exist in principle (I and Ia), and they cannot be easily distinguished



by ^1H NMR. However, X-ray analysis indicates that the dinitrophenyl group is bonded to the endocyclic nitrogen, as in I.

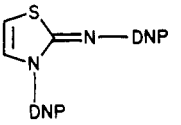
Bond lengths and valency angles of compound I are collected in Table II,[17] and Figure 1 is a perspective drawing of this compound. From the reported data the C_2–N_1 bond has a strong double bond character; in fact, its length (1.265 Å) is perfectly comparable with that of the analogous bonds of 2-[(2,6-dimethylphenyl)imino]-thiazolidine (1.264 Å),[5] 2-(phenylimino)thiazolidine (1.284 Å),[6] and similar systems.[7] The other geometrical parameters involving the C_2 atom are also in agreement with an exocyclic C–N double bond. The N_3 deviation from the plane of the heterocyclic ring is about 0.034 Å, while the deviation calculated for the C_6 atom is 0.347 Å, as expected for an N_3 which is sp^3 in character. The angle between the two rings is ~48°.

This same behavior is observed for 2-(*sec*-butylamino)thiazole (see ^1H NMR data in Table I) whose reaction gives compound II in high yield and in the absence of detectable amounts of other reaction products. A compound analogous to Ia, of course, is not possible in this case.



II

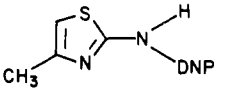
If the reaction of 2-aminothiazole is carried out in the presence of an excess of DNFB, the main reaction product is III, as is reasonably inferred from the ^1H NMR data



III

(Table I). This same compound (III) is also present, in low percentage (~10%), in the reaction mixtures initially containing equimolar amounts of the reactants and likely comes from a nucleophilic attack of the imino nitrogen of I on DNFB.

When the reaction is carried out with 4-methyl-2-aminothiazole, the main product is a crystalline orange compound (IV) whose structure has been assigned by

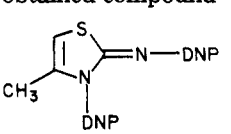


IV

X-ray analysis. ^1H NMR spectral data (Table I) show that the C_5–H signal is shifted at lower fields with respect to the corresponding signal of 4-methyl-2-aminothiazole (δ_{H_5} 6.08 in Me_2SO-d_6). This difference in chemical shift ($\Delta\delta$ = 0.9 ppm) is expected in view of the electronic effect of the dinitrophenyl group on this amino aromatic form. The structure of IV agrees with the structure previously proposed for the product of the reaction of 4-methyl-2-aminothiazole with picryl chloride.[8]

Figure 2 is a perspective drawing of compound IV, whose geometrical parameters are collected in Tables III and IV.[17] In this case the C_2–N_1 bond length (1.389 Å) is consistent with a single C–N bond,[9] and the geometrical parameters of the atoms of the thiazole ring agree well with the aromatic character of the heterocycle.[10] The angle between the rings is 172°. By examining the Fourier maps of IV it appears that the H_1 of the molecule A is bonded to the N_1 (exocyclic) atom, as expected for an amino tautomer. In principle, compound IV can exist in two tautomeric amino–imino forms, but in the solvent here considered and in the crystal state only the amino tautomer was detected in practice. This may be due to the fact that the electron-withdrawing ability of the 2,4-dinitrophenyl group is not sufficient to stabilize the imino form of this molecule.[1]

From the reaction mixture of 4-methyl-2-aminothiazole with DNFB is also obtained compound V as a side product,



V

in addition to IV which is the major product, even when DNFB is in molar excess (1:2). The ^1H NMR spectrum

(4) L. Forlani, submitted for publication in *Gazz. Chim. Ital.*
(5) G. Argay, A. Kalman, D. Lazar, B. Ribar, and G. Toth, *Acta Crystallogr., Sect. B*, **B33**, 99 (1977).
(6) D. Petrovic, B. Ribar, G. Argay, A. Kalman, and W Nowacki, *Acta Crystallogr., Sect. B*, **B33**, 106, (1977).
(7) A. Kalman, G. Argay, B. Ribar, and L. Toldy, *Tetrahedron Lett.*, 4241 (1977).
(8) S. S. Berg and V. Petrow, *J. Chem. Soc.*, 784 (1952).
(9) C. Cohen-Addad and M. P. Viallet, *Cryst. Struct. Commun.*, 341 (1978).
(10) G. R. Form, E. S. Raper, and T. C. Downie, *Acta Crystallogr., Sect. B*, **B30**, 342 (1974), and references there reported.

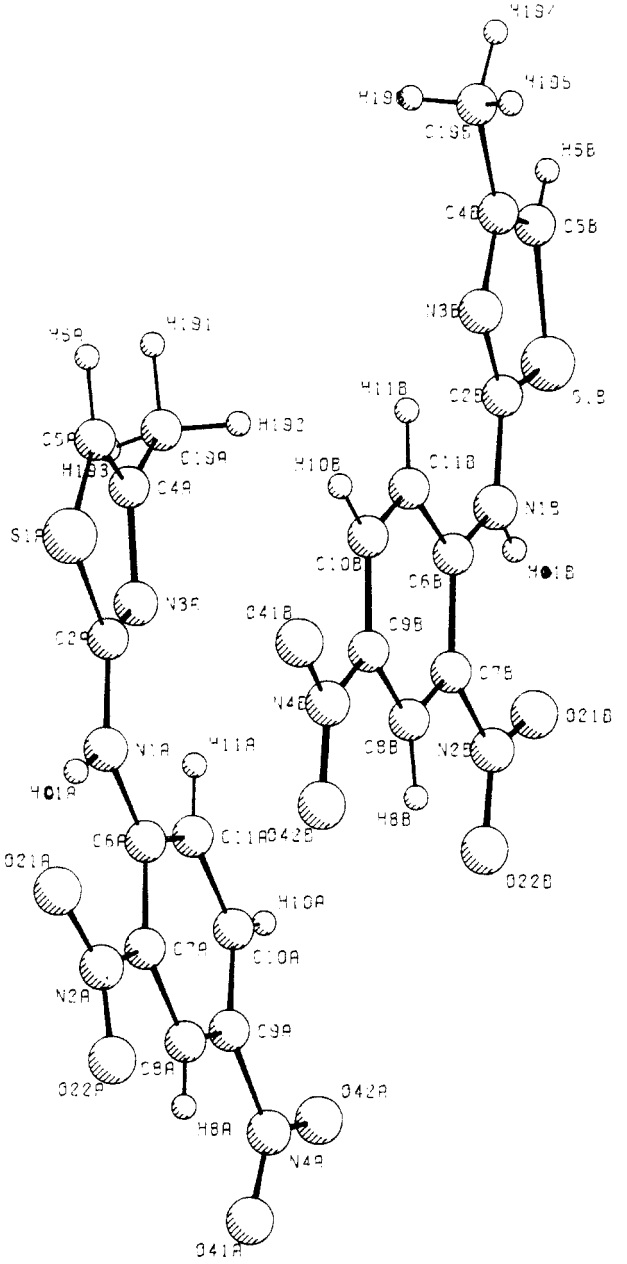
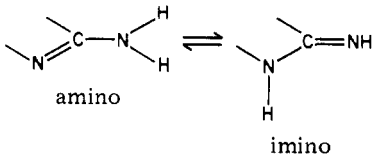


Figure 2. Perspective drawing and numbering scheme of compound IV.

of V is very similar to that recorded for III. We guess that this compound (V) comes from a nucleophilic attack of the compound analogous to I on DNFB. We have made sure that compounds I and IV do not isomerize even in the presence of DCl and after long reaction times (2–3 days). Compound IV does not react with DNFB in Me_2SO, while I is easily converted to III in the presence of DNFB in Me_2SO.

These findings agree with the reaction mechanism proposed by Coburn[11] for the reactions of 2-aminopyridine with picryl halides: i.e., products of structure III and V are obtained from a preliminary nucleophilic attack of the endocyclic nitrogen on the electrophilic center and subsequent further attack of the exocyclic nitrogen of the imino form. Both nitrogen atoms of the aminothiazole moiety are, in principle, nucleophilic sites although for any individual aminothiazole this nucleophilicity could well be related to actual position of the tautomeric equilibrium (eq 1). However, both aminothiazoles here considered are



(1)

known to exist essentially in the amino aromatic form in water[12] and Me_2SO.[4] In addition, the value of a prototropic equilibrium constant, in general, may be irrelevant in explaining the product formation.[13] The substantial differences observed when a methyl group is in position 4 can therefore hardly be explained as a consequence of tautomerism. Instead it is reasonable to attribute the different behavior of 2-aminothiazole and 4-methyl-2-aminothiazole toward DNFB to steric hindrance operating in the transition state for the latter thiazole. It is known that the basic strengths of the "aza"[12] and imino[14] nitrogens are higher than that of the exocyclic amino nitrogen, and basicity could be a relevant parameter for explaining these present results. The "aza"nitrogen appears to be a more efficient nucleophile than amino nitrogen toward an sp^2 aromatic carbon, except when steric hindrance affects the reaction as in the case of 4-methyl-2-aminothiazole. The imino nitrogen appears also to be a very efficient nucleophilic center as shown by the formation of compounds III and V.

Experimental Section

Starting materials were commercial samples (Carlo Erba or Schilling) purified according to the literature. Melting points are uncorrected. ^1H NMR spectra were recorded by a JEOL (100 or 60 MHz) spectrometer. Sample dilution did not affect the chemical shifts of the various protons, including the N–H protons.

Reactions of 2-Aminothiazole with DNFB. A solution of 1.1 g (0.006 mol) of DNFB in 5 mL of Me_2SO was added dropwise to a Me_2SO solution (5 mL) of 0.6 g (0.006 mol) of 2-aminothiazole under vigorous stirring at 25 °C. After 2 days the red reaction mixture was poured onto water and neutralized with $NaHCO_3$. A red solid precipitates (mp 140–143 °C) which contains about 10% (^1H NMR) of compound III. Crystallization from $CHCl_3$ gave 1.4 g (87%) of I: mp 144–145 °C; mass spectrum, m/e 266 (M^+), 220 ($-NO_2$), 174 ($-NO_2$), 147 (–HCN). Anal. Calcd for $C_9H_6N_4O_4S$: C, 40.60; H, 2.27; N, 21.04. Found: C, 40.63, H, 2.45; N, 21.05.

Similar results were obtained when the molecular ratio of 2-aminothiazole to DNFB was 2:1. On the other hand, when the molecular ratio was 1:2, compound III was obtained in 90% yield, mp 187–188 °C (acetone). Anal. Calcd for $C_{10}H_8N_6O_8S$: C, 41.67; H, 1.87; N, 19.44. Found: C, 41.84; H, 2.03; N, 19.38.

If the same reaction was performed in methanol or ethanol, products I and III were obtained, but in much lower yield as DNFB solvolysis products were also formed.

Reactions of 4-Methyl-2-aminothiazole with DNFB. By the above-described procedure compound IV was obtained as the major reaction product in Me_2SO (about 60% yield) when the molecular ratios of the reactants were 2:1, 1:1, and 1:2. The solid product mixture again precipitates when the reaction mixture is poured onto water: mp 156–157 °C; mass spectrum, m/e 280 (M^+), 263 (–OH), 232 ($-NO_2$). Anal. Calcd for $C_{10}H_8N_4O_4S$: C, 42.86; H, 2.87; N, 19.99. Found: C, 42.64; H, 2.80; N, 19.62.

Compound V was also present as a minor reaction product in the solid mixture, its yield being not more than 30% in all cases; mp 210–211 °C. Furthermore, compound IV dissolved in Me_2SO at 25 °C in the presence of a large excess of DNFB remains unchanged after 4 days and can be quantitatively recovered.

(11) B. W. Harris, M. D. Coburn, and E. P. Papadopoulos, *J. Heterocycl. Chem.*, 13, 846, (1976).

(12) L. Forlani, P. De Maria, and A. Fini, *J. Chem. Soc., Perkin Trans. 2*, 1156 (1980).

(13) P. Beak, *Acc. Chem. Res.*, 10, 186 (1977).

(14) S. J. Angyal and C. L. Angyal, *J. Chem. Soc.*, 1461 (1952); L. Forlani and P. De Maria, work in progress.

According to the literature,[15] compound IV can be obtained from the reaction of 4-methyl-2-aminothiazole with 2,4-dinitrohalobenzene in ethanol and in the presence of sodium acetate. The melting point reported for the reaction product is 81 °C. Following this procedure, we were not able to obtain the described product. Instead the observed products (~90% yield) were 2,4-dinitrophenyl ethyl ether, unreacted DNFB and 4-methyl-2-aminothiazole, and 4-methyl-2-aminothiazolium 2,4-dinitrophenoxide.

X-ray Analysis. Preliminary lattice constants were obtained by least-squares methods from 25 reflections lying in the range $6° < \theta < 20°$. Relevant crystallographic data are summarized in Table V.[17] Intensity data were corrected for Lorentz and polarization effects but not for absorption.

For compound I 128 reflections with $F_o \leq 5\sigma(F_o)$ were taken as unobserved, after data reduction. The space group was assigned from the systematic extinctions ($h0l$, $l = 2n + 1$; $0k0$, $k = 2n + 1$). The structure was solved by direct methods and refined by full-matrix least-squares methods with the SHELX crystallographic program system.[16] The H atoms were geometrically positioned (assuming C–H = 1.08 Å). Isotropic refinement was performed for all nonhydrogen atoms, except for the S and C_2 atoms and the NO_2 groups. The weighting scheme was $4.27/[\sigma(Fo)^2 + 0.000092F_o^2]$. The final conventional agreement index was 0.048.

For compound IV the same procedure as described for I was used (see Table V). In this case the first map with $E \geq 1.2$ gave an unsatisfactory structure, as two molecules were present in the asymmetric unit. With $E = 1.1$, the position of the atoms was clearly revealed and a preliminary refinement allowed identification of some hydrogen atoms (H_{O1B}, see Figure 2). The other hydrogen atoms were geometrically positioned by subsequent refinement. For these hydrogen atoms only, a thermal parameter was used, while all the nonhydrogen atoms were refined by isotropic U values, except for the S atom and the nitro groups. The weighting scheme was $2.93/[\sigma(F_o)^2 + 0.00053F_o^2]$ and the final conventional agreement index was 0.068.

Acknowledgment. We thank Professor G. Valle (University of Padova) for the diffractometer measurements. This work was carried out with the financial assistance of the CNR (Roma).

Registry No. I, 77825-94-6; II, 77825-95-7; III, 77825-96-8; IV, 68557-42-6; V, 77825-97-9; 2-(*sec*-butylamino)thiazole, 1438-44-4; 2-aminothiazole, 96-50-4; 4-methyl-2-aminothiazole, 1603-91-4; DNFB, 70-34-8.

Supplementary Material Available: Tables I–XI consisting of physical and spectral data, bond lengths and angles, data collection information, fractional and thermal parameters (13 pages). Ordering information is given on any current masthead page.

(15) S. P. Gupta and S. Rani, *J. Indian Chem. Soc.*, **55**, 730, (1978).
(16) G. M. Sheldrick, "SHELX 76", University of Cambridge, Cambridge, England, 1976.
(17) Supplementary material.

Alkoxycarbenium Ions. Relative Thermodynamic Stabilities via Pairwise Equilibrations[1a,b,2]

Roderic P. Quirk,*[1c] Charles R. Gambill, and George X. Thyvelikakath

Department of Chemistry, University of Arkansas, Fayetteville, Arkansas 72701

Received November 19, 1980

Alkoxycarbenium ions were synthesized by direct O-alkylation of the corresponding carbonyl compounds with trimethyloxonium ion salts and methyl fluorosulfate. The thermodynamic stabilities of the alkoxycarbenium ions were determined by stepwise equilibrations of pairs of these ions via transalkylation with the corresponding carbonyl compounds in liquid sulfur dioxide as monitored by ^1H NMR. The structures, spectra, and stabilities of alkoxycarbenium ions have been compared with those of the corresponding hydroxycarbenium ions. In general, the relative stability order for alkoxycarbenium ions parallels the order of stabilities for the corresponding hydroxycarbenium ions.

Alkoxycarbenium ions (or carboxonium ions), **1**, have been postulated as intermediates in a vast number and variety of organic reactions.[3-18] Oxonium ion chemistry has been the subject of a text[19] and a review.[20] The chemistry of structurally related species has also been reviewed.[21-27]

(1) (a) Taken in part from the Ph.D. dissertation of C.R.G., University of Arkansas, Fayetteville, AR, 1978. (b) Presented in part at the 27th–31st Southeast–Southwest Combined Regional Meeting of the American Chemical Society, Memphis, TN, Oct 31, 1975, Abstract No. 461. (c) Present address: Michigan Molecular Institute, 1910 W. St. Andrews, Midland, MI 48640.
(2) Preliminary communication: Quirk, R. P.; Gambill, C. R. *J. Chem. Soc., Chem. Commun.* **1974**, 503.
(3) Streitwieser, A., Jr. "Solvolytic Displacement Reactions", McGraw-Hill: New York, 1962; p 103.
(4) Dusseau, C. H. V.; Schaafsma, S. E.; deBoer, T. J. *Recl. Trav. Chim. Pays-Bas* **1970**, *89*, 535.
(5) Cordes, E. H. *Prog. Phys. Org. Chem.* **1967**, *4*, 1.
(6) Cordes, E. H.; Bull, H. G. *Chem. Rev.* **1974**, *74*, 581.
(7) Patai, S., Ed.; "The Chemistry of the Ether Linkage"; Interscience: New York, 1967; p 309.
(8) Young, P. R.; Bogseth, R. C.; Rietz, E. G. *J. Am. Chem. Soc.* **1980**, *102*, 6268.
(9) Sheldon, R. A.; van Doorn, J. A. *Tetrahedron Lett.* **1973**, 1021.
(10) Deno, N. C.; Billups, W. E.; Kramer, K. E.; Lastomirsky, R. R. *J. Org. Chem.* **1970**, *35*, 3080.
(11) Olah, G. A.; Parker, D. G., Yoneda, N.; Pelizza, F. *J. Am. Chem. Soc.* **1976**, *98*, 2245.
(12) Ward, H. R.; Sherman, P. D. *J. Am. Chem. Soc.* **1967**, *89*, 4222; *1968*, *90*, 3812.
(13) Begue, J. P.; Charpentier-Morize, M.; Pardo, C. *Tetrahedron* **1975**, *31*, 1919, 2505.
(14) Smith, L. E. H.; Mohr, L. H.; Raftery, M. A. *J. Am. Chem. Soc.* **1973**, *95*, 7494.
(15) Dunn, D. M.; Bruice, T. C. *Adv. Enzymol.* **1973**, *37*, 1.
(16) Ryono, D. E.; Loudon, G. M. *J. Am. Chem. Soc.* **1976**, *98*, 1889, 1900.
(17) Olah, G.; Yoneda, N.; Parker, D. G. *J. Am. Chem. Soc.* **1976**, *98*, 2251, 7341.
(18) Nakai, T.; Wada, E.; Okawara, M. *Tetrahedron Lett.* **1975**, 1531.
(19) Perst, H. "Oxonium Ions in Organic Chemistry"; Academic Press: New York, 1971.
(20) Perst, H. In "Carbonium Ions"; Olah, G. A., and Schleyer, P. v. R. Eds.; Wiley-Interscience: New York, 1976; Vol. V.
(21) Pittman, C. U.; McManus, S. P.; Larsen, J. W. *Chem. Rev.* **1972**, *72*, 357.
(22) Granik, V. G.; Pyatin, B. M.; Glushkov, R. G. *Russ. Chem. Rev. (Engl. Transl.)* **1971**, *40*, 747.

0022-3263/81/1946-3181$01.25/0