(96), 91 (58), 77, 69 (52), 51; IR (neat) 3300 (s), 3050 (m), 1720 (vs), 1310 (vs), 1160 cm^{-1} (vs). On standing for several weeks, the enamide hydrolyzed completely to acetophenone.

Photolysis of 4-Methyl-4-phenyl-2-trifluoromethyl-Δ^2-oxazolin-5-one (1). A solution of 205 mg (0.843 mmol) of 4-methyl-4-phenyl-2-trifluoromethyl-Δ^2-oxazolin-5-one (1) and 2 mL of methyl acrylate in 230 mL of dry acetonitrile was irradiated for 8 h through a Vycor filter with a Hanovia 450-W medium pressure lamp. Solvent removal at reduced pressure followed by silica gel chromatography (Mallinckrodt Silicar CC-7) with methylene chloride elution gave 105 mg of a mixture containing, by NMR analysis, 52 and 34% of the *cis*- and *trans*-2-trifluoromethyl-4-carbomethoxy-5-methyl-5-phenyl-Δ^1-pyrrolines, respectively. The remainder of the material, 14%, was acetophenone. By repeated silica gel chromatography, eluting with methylene chloride, a pure sample of the cis pyrroline was obtained, having the following spectral data: NMR ($CDCl_3$) δ 1.85 (3 H, s), 3.1 (3 H, s), 2.9–3.7 (3 H, m), 7.0–7.2 (5 H, m); IR (neat) 1740 (vs), 1440 (m), 1200 (vs), 1150 cm^{-1} (vs); mass spectrum (70 eV) *m/e* (rel intensity) 285 (28), 270 (11), 266 (6), 254 (6), 226 (42), 199 (57), 198 (25), 104 (100), 103 (88), 91 (15), 77 (57).

Anal. Calcd for $C_{14}H_{14}F_3NO_2$: C, 58.95; H, 4.95; N, 4.91. Found: C, 58.92; H, 5.07; N, 4.98.

By the same method a small portion of the pure trans isomer was also obtained, having the following spectral data: NMR ($CDCl_3$) δ 1.48 (3 H, s), 2.8–3.6 (3 H, m), 3.7 (3 H, s), 7.0–7.2 (5 H, m); mass spectrum (70 eV) *m/e* (rel intensity) 285 (50), 270 (18), 266 (11) 254 (16), 226 (76), 199 (100), 198 (46), 179 (21), 104 (92), 103 (82), 91 (17), 77 (58).

Photolysis of 177.5 mg of 1 in the presence of 152.5 mg (2.24 mmol) of *trans*-piperylene in 230 mL of acetonitrile for 6.25 h followed by the same workup gave the same products in essentially identical yields. The concentration of quencher was sufficient to reduce the quantum yield to 10% of its original value if the reactive lifetime were 10^{-7} s, assuming $k_{\text{diff}} = 1 \times 10^{10}$ for acetonitrile.

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Registry No.—1, 62263-54-1; **2**, 4855-22-5; **3**, 62263-55-2; **4**, 62263-56-3; **6**, 52762-80-8; **7**, 6284-14-6; **9**, 57957-24-1; **10**, 62288-65-7; α-phenylalanine, 565-07-1; *N*-trifluoroacetyl-α-phenylalanine, 62318-98-3; trifluoroacetic anhydride, 407-25-0; methyl acrylate, 96-33-3.

References and Notes

(1) A. Wexler and J. S. Swenton, *J. Am. Chem. Soc.*, **98**, 1602 (1976).
(2) L. R. Sousa and M. R. Johnson, to be published.
(3) P. S. Jones, G. W. Kenner, J. Preston, and R. C. Sheppard, *J. Chem. Soc.*, 6227 (1965).
(4) (a) A. Padwa and S. I. Wetmore, Jr., *J. Am. Chem. Soc.*, **96**, 2414 (1974); (b) H. L. Slates, D. Taub, C. H. Kuo, and N. L. Wendler, *J. Org. Chem.*, **29**, 1424 (1964); (c) N. Gakis, M. Marky, H.-J. Hansen, H. Heimgartner, H. Schmid and W. E. Oberhanski, *Helv. Chim. Acta*, **59**, 2149 (1976).
(5) P. A. Levene and R. E. Steiger, *J. Biol. Chem.*, **93**, 581 (1931).
(6) The azlactone photolyzed was not identified in ref 4a, but we tentatively assume that it was either 2-methyl-4-phenyl-Δ^2-oxazolin-5-one or 2,4-diphenyl-Δ^2-oxazolin-5-one.
(7) W. Steglich and K. A. Wellenstein, unpublished work cited in W. Steglich, *Fortschr. Chem. Forsch.*, **12**, 77 (1969).
(8) H. Gotthardt, R. Huisgen, and H. O. Bayer, *J. Am. Chem. Soc.*, **92**, 4340 (1970).
(9) W. Steglich, P. Gruber, H. U. Heininger, and F. Kneidl, *Chem. Ber.*, **104**, 3816 (1971).
(10) P. Gruber, L. Muller, and W. Steglich *Chem. Ber.*, **106**, 2863 (1973).
(11) After identifying the thermolysis product of 1 we found a reference by Steglich et al.[10] to unpublished work by G. Hofle noting the stability of 1 even up to 200 °C.
(12) A. Padwa, M. Dharan, J. Smolanoff, and S. I. Wetmore, Jr., *J. Am. Chem. Soc.*, **95**, 1945 (1973).
(13) This behavior is described for *cis*- and *trans*-4-carbomethoxy-5-methyl-2-phenyl-Δ^1-pyrroline in ref 4a.
(14) A. Padwa and W. P. Koehn, *J. Org. Chem.*, **40**, 1896 (1975).
(15) W. C. Danen and C. T. West, *J. Am. Chem. Soc.*, **95**, 6872 (1973).
(16) P. J. Krusic, K. S. Chen, P. Meaken, and J. Kochi, *J. Phys. Chem.*, **78**, 2036 (1974).
(17) W. A. Sheppard, *J. Am. Chem. Soc.*, **87**, 2410 (1965).
(18) (a) P. J. Scheidler and J. R. Bolton, *J. Am. Chem. Soc.*, **88**, 371 (1966); (b) W. D. Blackley and R. R. Reinhard, *ibid.*, **87**, 802 (1965).
(19) It is conceivable that the trifluoromethyl group encourages 1,5 bond cleavage as much as or more than 4,5 bond cleavage; however, this seems less likely since the trifluoromethyl group at C-2 is cross-conjugated with the radical-like species which might be expected from 1,5 bond cleavage.
(20) β,γ-Unsaturated butyrolactones also lose carbon monoxide upon irradiation. See, for example, (a) A. Yogiv and Y. Mazur, *J. Am. Chem. Soc.*, **87**, 3520 (1965); (b) O. L. Chapman and C. L. McIntosh, *Chem. Commun.*, 383 (1971); (c) B. A. M. Onde-Alink, A. W. K. Chan, and C. D. Gutsche, *J. Org. Chem.*, **38**, 1993 (1973); (d) A. Padwa, D. Dehm, T. Oine, and G. A. Lee, *J. Am. Chem. Soc.*, **97**, 1837 (1975).
(21) P. Caramella and K. N. Houk, *J. Am. Chem. Soc.*, **98**, 6397 (1976).
(22) K. Yates, S. L. Klemenko, and I. G. Csizmadia, *Spectrochim. Acta., Part A*, **25**, 765 (1969).
(23) R. Brainard and H. Morrison, *J. Am. Chem. Soc.*, **93**, 2685 (1971).
(24) V. Stenberg in "Organic Photochemistry", Vol. 1, O. L. Chapman, Ed. Marcel Dekker, New York, N.Y., 1967, p 127.
(25) We thank Professor Peter J. Wagner for a useful discussion of electron transfer in this system.
(26) W. Kirmse, "Carbene Chemistry", Academic Press, New York, N.Y., 1964, p 207.
(27) (a) W. G. Dauben, L. Salem, and N. J. Turro, *Acc. Chem. Res.*, **8**, 41 (1975); (b) J. Michl, *Mol. Photochem.*, **4**, 243, 257 (1972); (c) J. Michl, *Top. Curr. Chem.*, **46**, 1 (1974).
(28) F. D. Lewis and C. E. Hoyle, *J. Am. Chem. Soc.*, **97**, 5950 (1975).
(29) An authentic sample of the enamide was prepared by the method of Padwa et al,[14] treating phenylmagnesium bromide first with acetonitrile and then with acetyl chloride. We were, however, unable to completely purify the material due to ready hydrolysis to acetophenone and acetamide.
(30) L. Skulski, G. C. Palmer, and M. Calvin, *Tetrahedron Lett.*, 1773 (1963).
(31) The signals at *m/e* 120, 105, 77, and 51 were due to acetophenone, present as an impurity in the sample.

Reaction of Organic Azides with Ethoxycarbonylnitrene

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The reaction of *n*-hexyl azide with ethoxycarbonylnitrene generated by α-elimination from *N*-(*p*-nitrobenzenesulfonoxy)urethane in nitromethane generates *n*-hexaldehyde ethoxycarbonylhydrazone, which arises from the initial formation and rearrangement of ethyl *n*-hexylazocarboxylate. Ethyl phenylazocarboxylate is produced and isolated from a similar reaction with phenyl azide. Studies employing various organic azides, solvents, reaction conditions, and additives indicate *n*-hexyl azide to be reactive toward singlet ethoxycarbonylnitrene with a major competing reaction being the crossover of ethoxycarbonylnitrene from its singlet to its triplet state.

As part of a research program designed to explore the interaction of organic azides and reactive intermediates,[1-3] we have examined the reactions of organic azides with ethoxycarbonylnitrene. Azide–nitrene reactions have been observed in studies of the photolysis of alkyl[4] and aryl[5] azides, and the thermolysis of carbamoyl,[6] aryl,[7-11] and sulfonyl[12] azides. In each of these studies the focus of interest was the chemistry of the azide or the resulting nitrene rather than the reaction of an azide with a nitrene intermediate. The specific purpose of this study, a preliminary report of which has appeared,[3] is the examination of the interaction of organic azides and ethoxycarbonylnitrene.

In numerous studies of azide decompositions, the formation of products, particularly azo compounds, can be explained either by the interaction of an azide with a nitrene intermediate or with some excited-state azide.[4,5,10,13] We have circumvented this ambiguity by using *N*-(*p*-nitrobenzenesulfonoxy)urethane[14] (NBSU) as a source of ethoxycarbonylnitrene (**4**).

$$\begin{array}{ccccccc} \mathrm{ArSO_2ONHCO_2Et} & + & \mathrm{Et_3N} & \rightleftharpoons & \mathrm{ArSO_2O\bar{N}CO_2Et} & + & \mathrm{Et_3NH^+} \\ \mathbf{1} & & & & \mathbf{2} & & \\ & & & & \downarrow & & \\ & & & & \mathrm{(Et_3NH)^+(ArSO_3)^-} & + & \mathrm{NCO_2Et} \\ & & & & \mathbf{3} & & \mathbf{4} \end{array} \qquad (1)$$

Results and Discussion

When equimolar amounts of *n*-hexyl azide (**5**) and NBSU (**1**) in nitromethane are treated with excess triethylamine at room temperature, products are generated as shown in Scheme I.

Scheme I

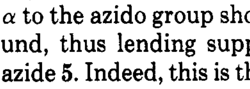
$$\begin{array}{l} \underset{\mathbf{5}}{n\text{-}\mathrm{C_6H_{13}N_3}} + \underset{\mathbf{1}}{\mathrm{ArSO_2ONHCO_2Et}} \xrightarrow{\mathrm{Et_3N}} \\ \underset{\substack{\mathbf{6}\\ 11\%}}{n\text{-}\mathrm{C_5H_{11}CH{=}NNHCO_2Et}} + \underset{\substack{\mathbf{3}\\ 95\%}}{\mathrm{(Et_3NH)^+(ArSO_3)^-}} \\ + \underset{\substack{\mathbf{7}\\ 14\%}}{\mathrm{EtO_2CNH_2}} + \underset{\substack{\mathbf{8}\\ 3\%}}{\mathrm{EtO_2CNHNHCO_2Et}} \end{array}$$

The major azide-derived product is *n*-hexaldehyde ethoxycarbonylhydrazone (**6**); 20% of azide **5** is decomposed, generating hydrazone in 55% yield, based on decomposed azide.[15] As discussed previously,[3] the azide is attacked by ethoxycarbonylnitrene rather than its anionic precursor **2** as shown by studies with added cyclohexene. The most reasonable explanation for the formation of the hydrazone is that the azide–nitrene reaction initially generates ethyl *n*-hexylazocarboxylate (**9**) which rearranges to the isolated hydrazone **6**.

$$\begin{array}{c} n\text{-}\mathrm{C_6H_{13}N_3} + \mathrm{NCO_2Et} \longrightarrow \underset{\mathbf{9}}{n\text{-}\mathrm{C_6H_{13}N{=}NCO_2Et}} \\ \downarrow \\ \underset{\mathbf{6}}{n\text{-}\mathrm{C_5H_{11}CH{=}NNHCO_2Et}} \end{array}$$

Ethyl *n*-hexylazocarboxylate (**9**), prepared by oxidation of *N*-*n*-hexyl-*N'*-ethoxycarbonylhydrazine, does indeed isomerize to *n*-hexaldehyde ethoxycarbonylhydrazone (**6**) at room temperature in ethanol (half-life 3 days), within 5 min in chloroform in the presence of a catalytic amount of triethylamine, or within 1 h in refluxing nitromethane. Unsuccessful attempts were made to isolate **9** from reactions run at 0 °C or to detect this proposed intermediate by monitoring the reaction mixture at 380 nm, where **9** exhibits an ultraviolet maximum.

Azo compounds bearing an α hydrogen to the azo group readily isomerize to the corresponding hydrazone.[16] Generation of ethoxycarbonylnitrene in the presence of an azide not bearing hydrogen α to the azido group should produce an isolable azo compound, thus lending support for the intermediacy of **9** from azide **5**. Indeed, this is the case with phenyl azide. Under conditions similar to standard runs with **5**, phenyl azide is decomposed (18%) and generates ethyl phenylazocarboxylate (**10**), the azo compound expected from the reaction of phenyl azide with ethoxycarbonylnitrene.



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Initially a search was made for a favorable solvent for the reaction of azide **5** and nitrene **4** with the results shown in Table I. A number of solvents (hexafluorobenzene, fluorotrichloromethane, 1,2-difluoro-1,1,2,2-tetrachloroethane, 1,1,2-trifluoro-1,2,2-trichloroethane) were not used because of the insolubility of NBSU. Other common solvents (alcohols, acetonitrile, pyridine, benzene) were not utilized because of their known reactivity with ethoxycarbonylnitrene. The lack of azide decomposition in tetramethylene sulfone and dimethoxyethane may well be accounted for by the reported reactivity of nitrenes with sulfoxides[17] and ethers,[18] respectively.

The reactivity of other organic azides was examined by determining the percent azide decomposition under the same reaction conditions as for **5**. The results, recorded in Table II, show the general trend one might expect when an azide is being attacked by electrophilic ethoxycarbonylnitrene: the nucleophilic alkyl azides are decomposed more efficiently than the electrophilic acyl and sulfonyl azides. Benzoyl azide and trimethylsilyl azide are unstable under the basic standard reaction conditions, an observation in accord with the known reactivity of acyl azides with amines[19] and silyl azides toward various nucleophiles.[20]

The 95% yield of triethylammonium *p*-nitrobenzenesulfonate (**3**) suggests that NBSU is quantitatively converted to ethoxycarbonylnitrene.[21] However, the maximum observed azide decomposition, with wide variations of solvent and azide structures, is only 22%. These results suggest that there are reactions of ethoxycarbonylnitrene in competition with the azide–nitrene reaction. Nitrenes are known to exist in singlet and triplet spin states which differ not only in electronic configurations but also in their reactivities.[24] Thus, it is conceivable that organic azides are more reactive toward one spin state of ethoxycarbonylnitrene than another. With these possibilities in mind, we initiated studies to determine the effect of reaction conditions on the efficiency of the azide–nitrene reaction, investigate possible side reactions, and determine the spin state of ethoxycarbonylnitrene that is reactive toward *n*-hexyl azide.

The first step in the production of ethoxycarbonylnitrene from NBSU is the reversible generation of the anionic precursor **3** of ethoxycarbonylnitrene (eq 1). A large excess of triethylamine should shift this equilibrium to the right,[25] minimizing side reactions involving NBSU, such as insertion of ethoxycarbonylnitrene into the N–H bond.[24] The results in Table III show that neither excess triethylamine (expt 6) and the use of triethylamine as solvent (Table I) nor the inverse addition of NBSU (expt 8, 9) had any appreciable effect upon percent azide decomposition. Another possibility, shown to occur in a similar system,[17] is attack by the nitrene on the anionic precursor **2**. Were this side reaction occurring to an appreciable extent, inverse addition of NBSU should increase azide decomposition, a result not observed (expt 8, 9).

Another side reaction to be considered is insertion of ethoxycarbonylnitrene into the carbon–hydrogen bonds of the *n*-hexyl azide. The extent of this reaction was determined by

Table I. Reaction of n-Hexyl Azide and Ethoxycarbonylnitrene in Various Solvents at 35 °C[a]

Solvent	% dec of n-$C_6H_{13}N_3$[b]	Solvent	% dec of n-$C_6H_{13}N_3$[b]
Dimethoxyethane	0	Dichloromethane	11
Tetramethylenesulfone	0	Nitrobenzene	13
Dibromomethane	3	N,N-Dimethylacetamide	14
Acetone	8	Nitromethane	20[c]
N,N-Dimethylformamide	9	Triethylamine	22[c,d]

[a] Initial concentration of n-hexyl azide and NBSU, 0.35 M; a 10% excess of Et_3N was used. [b] Experimental error ±2%. [c] Average value for several runs. [d] Inverse addition of NBSU.

Table II. Reaction of Various Azides with Ethoxycarbonylnitrene in Nitromethane at 35 °C[a]

Registry no.	Azide	% dec of azide[b]
	n-Hexyl azide	20
2101-87-3	p-Methoxyphenyl azide	18
622-37-7	Phenyl azide	18
24886-73-5	1-Azidoadamantane	16
14309-25-2	Trityl azide	15
3296-05-7	p-Chlorophenyl azide	11
817-87-8	Ethyl azidoformate	6
938-10-3	Benzenesulfonyl azide	4[c]
98-59-9	Tosyl azide	3[c]
582-61-6	Benzoyl azide	*d*
4648-54-8	Trimethylsilyl azide	*d*

[a] Initial concentration of azides and NBSU, 0.35 M; a 10% excess of Et_3N was used. [b] Experimental error ±2%. [c] CH_2Cl_2 used as solvent owing to instability of azide in nitromethane/triethylamine mixtures. [d] Unstable to reaction conditions.

Table III. Reaction of n-Hexyl Azide with Ethoxycarbonylnitrene in Nitromethane at 35 °C under Varied Reaction Conditions

Expt	Initial concn, M			% dec of azide[a]
	n-$C_6H_{13}N_3$	NBSU	Et_3N	
1	0.17	0.17	0.20	14
2	0.35	0.35	0.38	20[b]
3	0.70	0.70	0.75	25
4	0.70	0.35	0.38	12
5	0.35	0.70	0.75	28
6	0.35	0.35	1.40	19
7	0.35	0.35	0.38	21[c]
8	0.35	0.35	0.38	18[d]
9	0.35	0.70	0.75	28[d]
10	0.63	0.63	0.70	19[e]
11	0.63	0.63	0.70	22[d,f]

[a] Based on initial azide concentration; experimental error ±2.0%. [b] Standard reaction; average of numerous runs. [c] Simultaneous addition of NBSU and base. [d] Inverse addition of NBSU. [e] Average of two runs. [f] Azide decomposition determined by VPC analysis.

comparing azide decomposition as measured by infrared analysis with n-hexyl azide decomposition as measured by VPC. Insertion of the nitrene into a carbon–hydrogen bond on the n-hexyl group would result in a product, the azido absorption of which would be essentially indistinguishable by infrared analysis from the n-hexyl azide absorption. The VPC analysis is, however, quite specific for n-hexyl azide. The results from expt 10 and 11 of Table III indicate that insertion into carbon–hydrogen bonds of n-hexyl azide is not a major side reaction. An additional insertion process to be considered is the intramolecular reaction of the nitrene with the methyl carbon–hydrogen bond, producing 2-oxazolidone. Using VPC techniques with which a 2% yield could be detected, we found no 2-oxazolidone, in accordance with Lwowski's results.[26] Ethoxycarbonylnitrene may also dimerize to generate diethyl azodicarboxylate. This product was not produced in our system in detectable amounts (VPC analysis), an observation not surprising in light of the reported reactivity of azo compounds with nitrenes[27] and of diethyl azodicarboxylate toward triethylamine.[11]

One possible reaction of ethoxycarbonylnitrene is with the solvent, nitromethane. Conceivably, the nitrene could insert into the C–H bond or react with the nitro group. However, the observation of a greater percent azide decomposition in nitromethane (20%) than in dichloromethane (11%), a solvent known to be unreactive toward ethoxycarbonylnitrene,[28] suggests this not to be the source of any major side reaction. This was confirmed by VPC analysis of product mixtures from the generation of ethoxycarbonylnitrene in nitromethane in the presence and absence of n-hexyl azide, revealing one minor solvent-derived product, the structure of which was not determined.[29]

Experiments 1–5 of Table III have a direct bearing on the question of the spin state of ethoxycarbonylnitrene reacting with n-hexyl azide. These experiments show the effect of n-hexyl azide and NBSU concentrations on percent azide decomposition. Simultaneously increasing the azide and NBSU concentrations while maintaining a constant azide–NBSU ratio (expt 1, 2, 3) enhances the efficiency (amount of azide decomposed/mole of nitrene generated) of the azide–nitrene reaction, as does an increase in the azide–NBSU ratio (expt 2, 4, 5). Similar concentration effects upon absolute yields of products generated from nitrenes in hydrocarbon solvents have been observed by Lwowski[30] and Belloli.[31] Treatment of NBSU with triethylamine generates ethoxycarbonylnitrene exclusively in the singlet state. However, conversion to the triplet ground state competes quite favorably with intermolecular reactions, especially at low substrate concentrations.[28,32] In the reaction of ethoxycarbonylnitrene with *trans*-1,2-dimethylcyclohexane, a substrate–nitrene source ratio of 10:1 was not a sufficiently great excess of substrate to provide maximum yields of insertion products. It was concluded that the decomposition of the singlet nitrene was the side reaction responsible for reducing the insertion yields.[31] Such a possibility also exists within our system as most reactions were run with equimolar amounts of azide and NBSU, the nitrene source.

In our study of solvent effects upon azide decomposition, a noteworthy decrease in azide decomposition from 11% to 3% was observed in changing the solvent from dichloromethane to dibromomethane (Table I). The solvents differ very little in their chemical reactivities; thus, such a difference may be

Table IV. Effects of Additives on the Reaction of n-Hexyl Azide with Ethoxycarbonylnitrene in Nitromethane at 35 °C[a]

Expt	Additive	Concn, mol %	% dec of azide[b]	Absolute yield, %	
				3	7
1	None	0	20	95	14
2	CH_2Br_2	5	11		27
3	CH_2Br_2	10	7		27
4	CH_2Br_2	25	5		38
5	CH_2Br_2	50	0		40
6	CH_2Br_2	95	0		44
7	CH_2Br_2	100	3	88	14
8	CH_2Cl_2	100	11	95	9
9	$Ph(CH_3)C{=}CH_2$	5	13		11
10	$Ph(CH_3)C{=}CH_2$	10	13		11
11	$Cl_2C{=}CCl_2$	10	17		14
12	$Cl_2C{=}CCl_2$	20	18		14
13	N_2	*c*	18		
14	O_2	*d*	18		
15	None	*e*	15		
16	None	*f*	16		

[a] Initial concentration of *n*-hexyl azide and NBSU, 0.35 M; a 10% excess of Et_3N was used. [b] Based on initial azide concentration; experimental error ±2%. [c] Reaction mixture bubbled with N_2. [d] Reaction mixture bubbled with O_2. [e] Degassed, vacuum system apparatus. [f] Not degassed, using vacuum system apparatus.

explained either by assuming that dibromomethane stabilizes ethoxycarbonylnitrene more than dichloromethane and hence alters its reactivity, or that dibromomethane promotes singlet–triplet crossover of ethoxycarbonylnitrene and decreases the amount of singlet nitrene reacting with the azide. The reactivity of singlet nitrenes is solvent dependent. Previous reports have attributed solvent effects to either a stabilization of the singlet nitrene via formation of a solvent–nitrene complex (dichloromethane,[30,33] hexafluorobenzene[31,34]) or promotion of the singlet–triplet crossover rate by collisional deactivation of ethoxycarbonylnitrene (dibromomethane[35]). Anastassiou observed a decrease in the stereospecificity of cyanonitrene in dibromomethane relative to dichloromethane as a result of a "thermochemical heavy atom effect".[36] In the reaction of thermally generated ethoxycarbonylnitrene with 3-methylhexane, an increase in the production of triplet-derived ethyl carbamate and a decrease in singlet-derived insertion products were observed in going from dichloromethane to dibromomethane.[37] Belloli, in examining the reaction of thermally generated ethoxycarbonylnitrene with cyclohexene, also noted a reduction in singlet character upon dilution of cyclohexene with dibromomethane.[35]

In order to examine the multiplicity of the nitrene interacting with *n*-hexyl azide, a study was done on the effect of various additives upon azide decomposition. Also monitored was the production of ethyl carbamate (7), a product known to arise from triplet ethoxycarbonylnitrene.[26] The results are displayed in Table IV.

The obvious effect of diluting the nitromethane with dibromomethane is to decrease the observed azide decomposition while increasing the formation of the triplet-derived ethyl carbamate (expt 1–7), produced according to eq 2.

$$\mathrm{EtOCO\dot{N}\cdot} \xrightarrow{\mathrm{RH}} \mathrm{EtOCO\dot{N}H} \xrightarrow{\mathrm{R'H}} \underset{\mathbf{7}}{\mathrm{EtOCONH_2}} \qquad (2)$$

Thus, the effect of the dibromomethane is to promote singlet-triplet crossover of ethoxycarbonylnitrene. Addition of α-methylstyrene, known to be more reactive toward triplet than singlet ethoxycarbonylnitrene,[32] decreases azide decomposition and carbamate formation (expt 9, 10). The percent azide decomposition is not affected by the presence of oxygen (expt 13–16). However, it has been reported that oxygen reacts with triplet ferrocenyl[38] and aryl nitrenes[5,39] and effects triplet ethoxycarbonylnitrene reactions.[26,32,35]

These results are best explained by assuming *n*-hexyl azide to be reactive toward singlet ethoxycarbonylnitrene. No definitive statement concerning the reactivity of *n*-hexyl azide with triplet ethoxycarbonylnitrene can be made beyond the observation that the azide is much more reactive toward singlet than triplet ethoxycarbonylnitrene. The consistently small amount of azide decomposition observed under various reaction conditions suggests that the crossover of singlet to triplet ethoxycarbonylnitrene competes quite favorably with the reaction of the singlet ethoxycarbonylnitrene with *n*-hexyl azide. The use of a specific triplet nitrene trap, shown to be absolutely unreactive toward singlet nitrene, would shed light on this question; no such trap is presently known. Tetrachloroethylene has been used as such a trap for thermally generated ethoxycarbonylnitrene.[34] However, when up to 20 mol % tetrachloroethylene was added to nitromethane, we observed no effect upon either azide decomposition or ethyl carbamate (7) production (expt 1, 11, 12). This is in contrast to the effect observed by Breslow in the thermal generation of ethoxycarbonylnitrene from ethyl azidoformate.[34]

These results contrast with work done with alkyl[4] and aryl[5] nitrenes photolytically generated from alkyl and aryl azides. In both cases, the triplet nitrene was shown to react with the azide. Such a difference may be due to the different modes of formation of ethoxycarbonylnitrene and the alkyl and aryl nitrenes or to a larger difference in energy between the singlet and triplet alkyl and aryl[5] nitrenes than between singlet and triplet ethoxycarbonylnitrenes.[40]

Experimental Section

Infrared spectra and quantitative analyses were determined using a Beckman Acculab 3 or IR-8 spectrophotometer; ultraviolet spectra were recorded using a Coleman-Hitachi EPS-3T. Melting points were determined on a Mel-Temp apparatus; melting and boiling points are uncorrected. VPC analyses were determined on a Varian Aerograph Autoprep 700 with helium as carrier gas. Microanalyses were performed by Chemalytics, Tempe, Ariz.

Materials. The azides[41] and *N*-(*p*-nitrobenzenesulfonoxy)urethane (1)[14] were prepared by previously described methods. Triethylamine was dried over sodium hydroxide and fractionally distilled from α-naphthyl isocyanate. Reagent grade nitromethane was dried over Drierite before being distilled at 45 °C (97 mm).

n-Hexaldehyde Ethoxycarbonylhydrazone (6). Following the procedure outlined by Rabjohn and Barnstorff,[42] to *n*-hexaldehyde (30 g, 0.30 mol) dissolved in ethanol (105 mL) in a 250-mL round-bottomed flask sufficient water was added to cause turbidity and then ethanol was added to clear the solution. Glacial acetic acid (10 mL) and ethyl carbazate (30 g, 0.29 mol) were added and the mixture was refluxed with stirring for 1 h before removal of the solvent. The residue was recrystallized from 40% ethanol, producing **6** (30 g, 54%): mp 65–66 °C; IR ($CHCl_3$) 3375 (s), 1737 (s), 1710 cm^{-1} (s). Anal. Calcd for $C_9H_{18}N_2O_2$: C, 58.06; H, 9.68; N, 15.05. Found: C, 58.42; H, 10.18; N, 15.05.

***N*-n-Hexyl-*N*′-ethoxycarbonylhydrazine.**[43] A mixture of 6 (60 g, 0.32 mol), platinum oxide (1.14 g), and glacial acetic acid (150 mL) was added to a Parr pressure reaction bomb, which was sealed and charged with hydrogen at a pressure of 50 psi. The reaction mixture was stirred for 3 h with maintenance of the hydrogen pressure at 50 psi, after which the mixture was filtered. The filtrate was washed with water (140 mL); the aqueous layer was extracted with three 200-mL portions of ethyl ether; the combined organic layers were washed with 10% $NaHCO_3$ until basic and twice with water, dried (Na_2SO_4), filtered, and evaporated on a rotary evaporator. The resulting light yellow oil was fractionally distilled at 98 °C (0.8 mm), producing *N*-*n*-hexyl-*N*′-ethoxycarbonylhydrazine (14.3 g, 26%): IR (CCl_4) 3340 (s), 1718 cm^{-1} (s). Anal. Calcd for $C_9H_{20}N_2O_2$: C, 57.45; H, 10.64; N, 14.89. Found: C, 57.61; H, 10.88; N, 14.92.

Ethyl *n*-Hexylazocarboxylate (9).[43] *N*-*n*-Hexyl-*N*′-ethoxycarbonylhydrazine (8.9 g, 0.05 mol) and 45 mL of a saturated sodium chloride solution were added to a three-necked 500-mL round-bottomed flask equipped with a stirrer, an additional funnel, and a drying tube, and cooled by a dry ice–isopropyl alcohol bath to −15 °C. Bromine (7.9 g, 0.05 mol) in 200 mL of water was added over a 4-h period. After stirring for 1.5 h, the mixture was extracted with two 100-mL portions of cold ethyl ether; the combined ether layers were washed with 10% $NaHCO_3$ and water and dried ($MgSO_4$). Removal of solvent produced 3 mL of **9** as a bright red oil: IR ($CHCl_3$) 1755 cm^{-1} (s); UV (EtOH) 380 nm. IR analysis of the oil showed no peaks characteristic of either *N*-*n*-hexyl-*N*′-ethoxycarbonylhydrazine or **6**.

Ethyl Phenylazocarboxylate (10). To a 100-mL round-bottomed flask containing 60 mL of CH_2Cl_2, 4 mL of pyridine, and 3.6 g (20 mmol) of *N*-phenyl-*N*′-ethoxycarbonylhydrazine[44] was added 3.5 g (20 mmol) of NBS at −20 °C over a 25-min period. After stirring at room temperature for 30 min, the solution was washed twice with dilute sodium thiosulfate, water, 2 N HCl, 10% sodium bicarbonate, and water. After drying and removal of solvent, the resulting red mixture was distilled, giving 1.0 g (31%) of **10**, a red oil: bp 90–92 °C (0.9–1.1 mm); IR ($CHCl_3$) 1740 cm^{-1} (s); UV (dioxane) 287, 424 nm. Anal. Calcd for $C_9H_{10}N_2O_2$: C, 60.67; H, 5.61; N, 15.73; Found: C, 58.42; H, 5.72; N, 15.96.

Reaction of *n*-Hexyl Azide (5) with Ethoxycarbonylnitrene Generated from NBSU (1). To a three-necked flask equipped with a $CaCl_2$ drying tube and charged with *n*-hexyl azide (1.27 g, 0.01 mol), NBSU (2.90 g, 0.01 mol), and 25 mL of nitromethane, was added triethylamine (1.21 g, 0.012 mol) over a period of 45 min. The reaction mixture was then stirred for 3 h in the dark.

For quantitative infrared analyses of azide decomposition, the azido group absorbance at 2095 cm^{-1} was determined using matched sodium chloride cells. Beer's law plots of the azido group absorbance were found to be linear in the concentration range employed. For VPC determination of *n*-hexyl azide, bromobenzene was used as an internal standard under the following conditions: 5 ft × 0.125 in., 10% OV-1 on 60/80 Chromosorb W, 68 °C.

For experiments involving the other organic azides, the reaction was run on a scale such that the total volume of the reaction mixture was 8 mL. Upon completion of the reaction, the reaction mixture was transferred into a 10-mL volumetric flask and the 15-mL round-bottomed reaction flask rinsed with small amounts of nitromethane until the volumetric was filled to the mark. Infrared analyses for azide decomposition on these solutions agreed well with those of larger runs. For the reactions run under a nitrogen atmosphere or when saturated with oxygen, the solvent was saturated with the gas by a bubbling device and a steady stream of the gas was utilized over the 3-h reaction time. In the degassing experiments, a simple device was fabricated by which separate mixtures of **5**, **1**, and nitromethane (solution 1) and triethylamine and nitromethane (solution 2) were degassed through three freeze–thaw cycles before solution 2 was distilled into the compartment containing solution 1. The simultaneous addition of triethylamine and **1** was effected by using two addition funnels charged with solutions of the amine and of **1** and adding these dropwise to azide **5** dissolved in nitromethane. The inverse addition of **1** was effected by the addition of the solid reagent **1** to a mixture of azide **5**, amine, and solvent over a 40-min period. In experiments involving additives, the additive was present in the reaction mixture prior to the addition of the triethylamine.

Isolation and Quantitative Analyses of Products from the Reaction of *n*-Hexyl Azide (5) with Ethoxycarbonylnitrene Generated from NBSU (1). Upon completion of the reaction, most of the nitromethane was removed under vacuum and ether was added to precipitate triethylammonium *p*-nitrobenzenesulfonate (**3**), which was quantified gravimetrically. For isolation of **6**, **7**, and **8**, the reaction mixture was distilled at 33 °C (55 mm), yielding a mixture of **5** and nitromethane. To the residue was added 25 mL of water and 20 mL of pentane. The layers were separated, the aqueous layer washed with pentane, and the combined organic layers dried prior to distillation at 34 °C (17 mm), yielding more azide **5**. Pure *n*-hexaldehyde ethoxycarbonylhydrazone (**6**) was isolated from the residue by preparative VPC (5 ft × 0.25 in., 10% SF-96 on 60/80 Chromosorb W, 173 °C). Similar conditions (6 ft × 0.375 in., 20% SF-96 on 60/80 Chromosorb A, 150 °C) were employed for isolation of ethyl carbamate (**7**) and *N*,*N*′-diethoxycarbonylhydrazine (**8**).

For quantitative VPC analyses of products **6**, **7**, and **8**, the reaction was run as previously described and the mixture diluted to the mark in a volumetric flask. Relative peak areas were determined by weighing of peaks cut from photostatic copies. Owing to the composition of the product mixtures, internal standards could not be used. To determine absolute yields, the peaks from aliquots of the reaction mixture were compared with those of standard solutions. The error was taken to be twice the standard deviation found. The following conditions were used: for **6**, 6 ft × 0.125 in., 10% SF-96 on 60/80 Chromosorb W, 145 °C; for **7**, 5 ft × 0.25 in., 20% XF-1150 on 45/60 Chromosorb W, 132 °C; for **8**, same as for **7** except 190 °C.

Rearrangement of Ethyl *n*-Hexylazocarboxylate (9) to *n*-Hexaldehyde Ethoxycarbonylhydrazone (6). **9** (2 mL) was added to 5 mL of chloroform and 0.5 mL of triethylamine. The disappearance of the azo compound **9**, as indicated by infrared analysis, was complete within 30 min. The solution was concentrated under vacuum and the residue recrystallized three times from 40% ethanol. The solid melted at 62–63 °C; a mixture with pure **6** also melted at 62–63 °C. A dichloromethane solution of azide **5** and **9** was stable at room temperature for 24 h. Upon addition of an equimolar amount of triethylammonium *p*-nitrobenzenesulfonate and stirring for 12 h, infrared analysis indicated almost quantitative rearrangement of **9** to **6**. This same rearrangement is effected by refluxing a nitromethane solution of **9** for 1 h.

Reaction of Phenyl Azide with Ethoxycarbonylnitrene Generated from NBSU (1). Ethoxycarbonylnitrene was generated from **1** in methylene chloride in the presence of phenyl azide in a manner similar to that described for **5**. Addition of water, washes with 2 N HCl, 10% $NaHCO_3$, and water, drying ($MgSO_4$), and removal of solvent produced an oily residue analyzed by preparative TLC (6 × 6 in., 2 mm silica gel). Development twice with benzene produced four distinct bands, the third one of which yielded a compound having the same R_f value on silica gel and identical infrared and ultraviolet spectra as ethyl phenylazocarboxylate (**10**): IR (CH_2Cl_2) 1740 cm^{-1} (s); UV (dioxane) 287 nm.

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Registry No.—**1**, 2955-74-0; **3**, 4113-69-3; **4**, 2655-26-7; **5**, 6926-45-0; **6**, 50785-98-3; **7**, 51-79-6; **8**, 4114-28-7; **9**, 50785-99-4; **10**, 943-76-0; *n*-hexaldehyde, 66-25-1; ethyl carbazate, 4114-31-2; *N*-*n*-hexyl-*N*′-ethoxycarbonylhydrazine, 50786-00-0; *N*-phenyl-*N*′-ethoxycarbonylhydrazine, 6233-02-9.

References and Notes

(1) J. E. Leffler and H. H. Gibson, Jr., *J. Am. Chem. Soc.*, **90**, 4117 (1968).

(2) H. H. Gibson, Jr., J. R. Cast, J. Henderson, C. W. Jones, B. F. Cook, and J. B. Hunt, *Tetrahedron Lett.*, 1825 (1971).

(3) H. H. Gibson, Jr., C. H. Bundy, and H. R. Gaddy III, *Tetrahedron Lett.*, 3801 (1973).

(4) C. L. Currie and B. deB. Darwent, *Can. J. Chem.*, **41**, 1552 (1963).

(5) A. Reiser, F. W. Willets, G. C. Terry, V. Williams, and R. Marley, *Trans. Faraday Soc.*, **64**, 3265 (1968).

(6) T. Curtius, *Angew. Chem.*, **27**, 213 (1914).

(7) A. Bertho, *Ber.*, **57**, 1138 (1924).

(8) G. Smolinsky, *J. Org. Chem.*, **26**, 4108 (1961).

(9) L. Horner, A. Christmann, and A. Gross, *Ber.*, **96**, 399 (1963).

(10) P. A. S. Smith in "Nitrenes", W. Lwowski, Ed., Wiley, New York, N.Y., 1970, pp 114–119.

(11) W. Lwowski, T. W. Mattingly, Jr., and T. Maricich, *Tetrahedron Lett.*, 1591 (1964).

(12) J. H. Hall and E. Petterson, *J. Am. Chem. Soc.*, **89**, 5856 (1967).

(13) R. A. Abramovitch and G. N. Knaus, *J. Org. Chem.*, **40**, 883 (1975).

(14) W. Lwowski and T. J. Maricich, *J. Am. Chem. Soc.*, **87**, 3630 (1965).

(15) The yield of hydrazone **6**, based on decomposed **5**, varied between 20 and 55% depending upon solvent, concentration of reagents, and mode of addition of **1**. In separate experiments it was found that hydrazone **6** is reactive toward nitrene **4** generated from **1** or thermally from ethyl azidoformate. Consequently the extent of reaction between azide and nitrene is measured by determining the percent azide decomposition rather than percent **6** formed. This procedure assumes that the principal, if not exclusive, pathway for azide decomposition is via reaction with **4**. The observed stability of the azides in the presence of various reactants and products, as well as the effect of added cyclohexene upon azide **5** decomposition,[3] lends support for such an assumption.

(16) H. Zollinger, "Azo and Diazo Chemistry, Aliphatic and Aromatic Compounds", Interscience, New York, N.Y., 1961, p 327.

(17) W. Lwowski in "Nitrenes", W. Lwowski, Ed., Wiley, New York, N.Y., 1970, p 216.

(18) H. Nozaki, S. Fugita, H. Takaya, and R. Noyori, *Tetrahedron*, **23**, 45 (1967), and references cited therein.

(19) P. A. S. Smith, "The Chemistry of Open-Chain Nitrogen Compounds", Vol. II, W. A. Benjamin, New York, N.Y., 1966, p 246 ff.

(20) C. H. Van Dyke in "Organometallic Compounds of the Group IV Elements", Vol. 2, Part I, A. G. MacDiarmid, Ed., Marcel Dekker, New York, N.Y., 1972, p 253 ff.

(21) One possible reaction of the anion **2** which would generate the salt **3** without producing ethoxycarbonylnitrene is the Lossen rearrangement.[22] Such

a rearrangement of anion **2**, unfavorable because of the required migration of the ethoxy group, has been shown to occur only to a slight extent under similar conditions.[23]

(22) P. A. S. Smith in "Molecular Rearrangements", Vol. I, P. de Mayo, Ed., Wiley, New York, N.Y., 1963, p 528.

(23) T. J. Maricich, Thesis, Yale University, New Haven, Conn., 1965.

(24) W. Lwowski in "Nitrenes", W. Lwowski, Ed., Wiley, New York, N.Y., 1970, Chapter 6.

(25) Rapid addition of an equimolar amount of triethylamine to NBSU and *n*-hexyl azide in nitromethane resulted in the instantaneous disappearance of the N-H peak of NBSU at 3290 cm^{-1}; the usual 20% azide decomposition is complete within 90 s.

(26) W. Lwowski and T. W. Mattingly, *J. Am. Chem. Soc.*, **87**, 1947 (1965).

(27) R. C. Kerber and P. J. Heffron, *J. Org. Chem.*, **37**, 1592 (1972).

(28) W. Lwowski and F. P. Woerner, *J. Am. Chem. Soc.*, **87**, 5491 (1965); W. Lwowski and J. S. McConaghy, Jr., *ibid.*, **87**, 5490 (1965).

(29) Generation of nitrene **4** from **1** in nitromethane in the presence or absence of **5** produces a reddish-orange solution and carbon dioxide as a major gaseous component, as analyzed by mass spectrometry. Removal of nitromethane and salt **3** leaves a reddish-brown tarry residue, from which **6**, **7**, and **8** can be isolated.

(30) G. R. Felt, S. Linke, and W. Lwowski, *Tetrahedron Lett.*, 2037 (1972); G. R. Felt and W. Lwowski, *J. Org. Chem.*, **41**, 96 (1976).

(31) R. C. Belloli and V. A. LaBahn, *J. Org. Chem.*, **40**, 1972 (1975).

(32) J. S. McConaghy, Jr., and W. Lwowski, *J. Am. Chem. Soc.*, **89**, 2357 (1967).

(33) P. A. Tardella, L. Pellacani, G. DiStazio, and M. Virgillito, *Gazz. Chim. Ital.*, **104**, 479 (1974); R. C. Belloli, M. A. Whitehead, R. H. Wollenberg, and V. A. LaBahn, *J. Org. Chem.*, **39**, 2138 (1974).

(34) D. S. Breslow and E. I. Edwards, *Tetrahedron Lett.*, 2041 (1972).

(35) R. C. Belloli, R. H. Wollenberg, and J. P. Jaegar, *J. Org. Chem.*, **37**, 1857 (1972).

(36) A. G. Anastassiou, *J. Am. Chem. Soc.*, **89**, 3184 (1967).

(37) J. M. Simson and W. Lwowski, *J. Am. Chem. Soc.*, **91**, 5107 (1969).

(38) R. A. Abramovitch, C. I. Azogu, and R. G. Sutherland, *Chem. Commun.*, 134 (1971).

(39) R. A. Abramovitch and S. R. Challand, *J. Chem. Soc., Chem. Commun.*, 964 (1972).

(40) (a) R. S. Berry in "Nitrenes", W. Lwowski, Ed., Wiley, New York, N.Y., 1970, p 41 ff; (b) P. F. Alewood, P. M. Kazmaier, and A. Rauk, *J. Am. Chem. Soc.*, **95**, 5466 (1973); (c) J. F. Harrison and G. Shalhoub, *ibid.*, **97**, 4172 (1975).

(41) M. E. C. Biffin, J. Miller, and D. B. Paul in "The Chemistry of the Azido Group", S. Patai, Ed., Wiley, New York, N.Y., 1971, Chapter 2.

(42) N. Rabjohn and H. D. Barnstorff, *J. Am. Chem. Soc.*, **75**, 2260 (1953).

(43) C. G. Overberger and A. V. Digiulio, *J. Am. Chem. Soc.*, **80**, 6567 (1958).

(44) O. Widman, *Chem. Ber.*, **28**, 1925 (1895).

Azaindolizines. 4. Synthesis and Formylation of 8-Azaindolizines

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The 8-azaindolizines (**1–10**) were synthesized by a Chichibabin reaction between 2-methylpyrimidines and an α-halo ketone. 2-Methylpyrimidine itself gave in low yield 2-carbethoxy- (**2**), 2-methyl- (**3**), 2,3-dimethyl- (**4**), and 2-phenyl-8-azaindolizine (**5**) when reacted with ethyl bromopyruvate, bromoacetone, 3-bromobutanone, and phenacyl bromide; hydrolysis and decarboxylation of **2** gave the parent system (**1**). 2,4-Dimethylpyrimidine similarly gave **6** and **7** with bromoacetone and 3-bromobutanone. 2-Methyl-4-methoxypyrimidine when reacted with phenacyl bromide and bromoacetone gave the expected 7-methoxy-8-azaindolizine structures **8** and **9** along with the 8-methyl-8-azaindolizinones **22**, **23**, and **32**. 2-Methyl-4-hydroxypyrimidine with bromoacetone gave **25** and **34**. The structures of the 8-azaindolizines isolated were deduced from their ^{1}H NMR spectra and the ^{1}H NMR spectra of their formyl derivatives. Formylation has been shown to occur preferentially at C-3, and 1,3-dipolar addition of dimethyl acetylenedicarboxylate with **6** and **23** occurs to give the corresponding 5-azacycl[3.2.2]azines **37** and **38**.

Substituted 8-azaindolizines have been prepared chiefly by reaction of a 1,3-dicarbonyl compound with a 2-aminopyrrole stabilized by electron-withdrawing groups.[1] An alternative direct synthetic route to 8-azaindolizines would be to employ the Chichibabin reaction[2] between a 2-methylpyrimidine and an α-halo ketone. The simplest and first reported 8-azaindolizine, 5,7-dimethyl-2-phenyl-8-azaindolizine (**11**), was claimed[3] to be obtained by this route using 2,4,6-trimethylpyrimidine and phenacyl bromide; recently we showed[4] that the product of this reaction is the isomeric 5,7-dimethyl-2-phenyl-6-azaindolizine (**14**). In this paper we report the synthesis of the parent 8-azaindolizine (**1**) and several simple derivatives by reaction of a 2-methylpyrimidine with a number of α-halo ketones. The structures of the 8-azaindolizines isolated were determined from their ^{1}H NMR spectra, shown in Table I, and the ^{1}H NMR spectra of their formylated derivatives. The assignments of the protons in these structures were made on the basis of their proximity to nitrogen, by the assistance of double irradiation, by deuterium exchange,[5,6] and by a comparative examination of related spectra.

Reaction between 2-methylpyrimidine and ethyl bromopyruvate gave a product whose infrared and ^{1}H NMR spectra indicated it to be 2-carbethoxy-8-azaindolizine (**2**). The ^{1}H NMR spectrum showed a 2 H methylene quartet and a 3 H methyl triplet at δ 4.38 and 1.37 assigned to the carbethoxy ethyl group, two lower field 1 H singlets at δ 7.03 and 7.71 assigned to H-1 and H-3, respectively, a 1 H complex signal approximating to a triplet at δ 6.58 assigned to H-6, and a 2 H doublet at δ 8.14 assigned to H-5 and H-7. Alkaline hydrolysis of the ester (**2**) followed by neutralization and decarboxylation gave the parent 8-azaindolizine (**1**) as a yellow oil, stable in vacuo but which decomposed rapidly on exposure to air; the ^{1}H NMR spectrum of **1** is shown in Figure 1. The 1 H apparent triplet at δ 6.98 is assigned to H-2 since it is coupled with the adjacent H-1 and H-3 protons. The H-1 and H-3 signals are weakly coupled to each other and occurred as differentially exchangeable[7] multiplets at δ 6.64 and 7.19, respectively. The 1 H apparent quartet centered at δ 6.48 is assigned to H-6, its multiplicity arising mainly from coupling with H-5 and H-7. The two lower field overlapping multiplets at δ 8.00–8.24 were assigned to H-5 and H-7. Irradiation at δ 6.48 simplified the multiplet at δ 8.00–8.24 to two broad singlets and to some extent sharpened the H-3 signal at δ 7.19. Support for the above assignments was provided from the ^{1}H NMR spectrum of its formyl derivative (**17**). The spectrum of **17**, when compared to the spectrum of **1**, showed the absence of the H-3 multiplet, the emergence of a 1 H formyl singlet at δ 9.73, and a marked downfield shift (ca. 170 Hz) of the position of one of the lower field signals; such a shift can only be accounted for by the anisotropic deshielding effect of a 3-formyl group via its peri orientation to H-5. 2-Methylpyrimidine reacted with bromoacetone, bromobutanone, and phenacyl bromide to give 2-methyl- (**3**), 2,3-dimethyl- (**4**), and 2-phenyl-8-azaindolizine (**5**).

Reaction between 2,4-dimethylpyrimidine and phenacyl