DEPROTONATIONS OF TERNARY IMINIUM SALTS

By

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To Jean

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By

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Chairman: James A. Deyrup
Major Department: Chemistry

The deprotonation of ternary iminium salts as a method for synthesizing aziridines *via* azomethine ylides was investigated. The salts were prepared by alkylating ketimines and aldimines with methyl fluorosulfonate. A variety of strong bases (but poor nucleophiles) were studied as potential deprotonating agents. In one case, the ketiminium salt *N*-(benzhydrylidene)methyl-*tert*-butylaminium fluorosulfonate was converted to 1-*tert*-butyl-2,2-diphenylaziridine in excellent yield, upon treatment with the base sodium bis(trimethylsilyl)amide in hexane.

Different results were obtained with the structurally related aldiminium salt *N*-(benzylidene)methyl-*tert*-butylaminium fluorosulfonate, under the same reaction conditions.

The expected 1-tert-butyl-2-phenylaziridine was not detected in the crude product mixture. Instead, the isolated and characterized products were α,α'-bis(methyl-tert-butylamino)stilbene, and two aminomethylaziridine diastereoisomers. Mechanisms that are consistent with these observations are discussed.

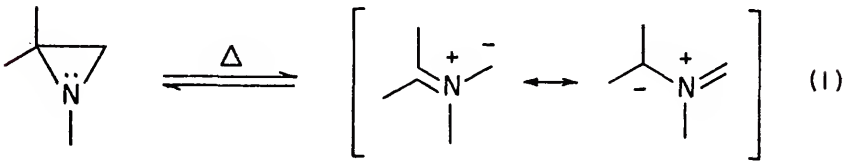
Two approaches to the synthesis of the unknown, potentially antiaromatic 2-azirine system were tested. The first approach involved the treatment of certain heterosubstituted iminium salts with a strong base, in an effort to generate aziridines which could be transformed in situ to 2-azirines. The second approach was the attempted alkylation and subsequent deprotonation of the known 1-azirine isomers. The major product of the treatment of 2,3-diphenyl-1-azirine with methyl triflate was the novel, alkylated dimer 2-H-3,4,6,7-tetraphenyl-2,5-diaza-2,4,6-heptatrienium triflate. However, neither approach provided evidence for the formation of the 2-azirine system.

CHAPTER I

APPLICATIONS TO THE SYNTHESIS OF AZIRIDINES

Introduction

The reversible thermal ring openings of aziridines (1) to resonance-stabilized azomethine ylides (2) are well-known reactions.[1,2] The classical trapping experiments of Huisgen,[1] for example, have provided convincing tests of the Woodward-Hoffmann rules of orbital



(1)

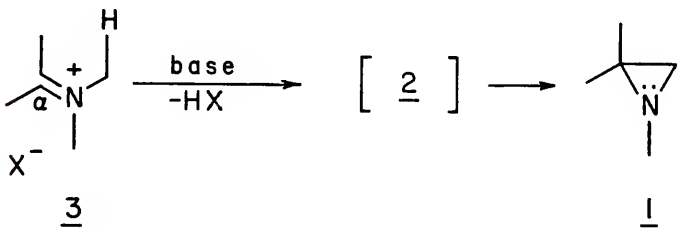
1 2

symmetry,[3] and have contributed significantly to the area of 1,3-dipolar cycloadditions.

In spite of their impact on mechanistic organic chemistry, these thermolytic reactions are of little synthetic use for the preparation of aziridines. It was the plan of this research to generate 1,3-dipolar intermediates from non-aziridine precursors, thereby rendering this a practical method for the synthesis of aziridines.

Although azomethine ylides have been generated from

several non-aziridine precursors,[4] the ternary iminium salts of type 3 seemed to offer the most general route to functionally substituted 1,3-dipoles: deprotonation of 3 with a suitable base would afford the desired



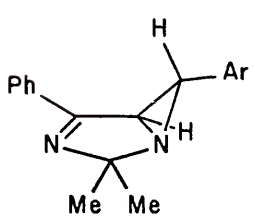
3 1 (2)

intermediate 2 which, it was hoped, would cyclize to the aziridine, as shown in equation 2. The choice of which iminium salts to use was subject to several structural constraints: (1) the salt had to bear substituents which would, both electronically and sterically, encourage intramolecular cyclization of the incipient ylide; (2) the substituents on the α-carbon atom of 3 had to be devoid of protons, to preclude enamine formation upon treatment with base; and (3) the anion X^- had to be sufficiently non-nucleophilic that it did not interfere with the reaction chemically.

In principle, one could encourage intramolecular isomerization of 2 by utilizing very reactive azomethine ylides, whose lifetime was sufficiently short that intermolecular reaction was not a competing process. The reactivity of azomethine ylides, in turn, is a function of both electronic and steric factors. Huisgen[1] has shown,

for example, that electron-withdrawing groups attached to the dipolar termini decrease the reactivity of the ylides, relative to the effect of electron-donating substituents. These electronic effects on dipolar reactivity are reflected in the temperatures that are required to effect the ring opening (equation 1) of different aziridines: the higher the temperature, the more reactive the resulting azomethine ylide. Thus, whereas 2,3-dicarbethoxyaziridines cleave at 100°C,[1a] the corresponding 2,3-diphenyl derivatives require refluxing in toluene for 11 hours.[2a]

Steric factors also influence the tendency of 1,3-dipoles to undergo intramolecular cyclization. When relief of strain accompanies the ring opening of certain bicyclic aziridines, for example 4[2b] and 5,[2e] the resulting azomethine ylides are found to be particularly stable to the reverse process of ring closure. This effect is also



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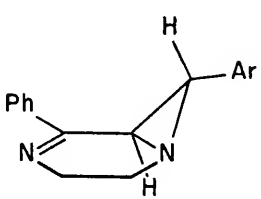

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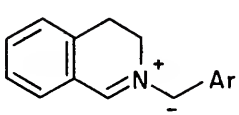
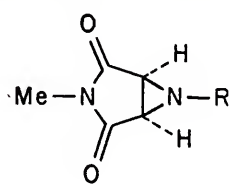


6

Ar = p-nitrophenyl

partially responsible for the total reluctance of the first reported azomethine ylide, 6,[4a] to isomerize to the corresponding aziridine. The stability of 6 (and of the ylides derived from 4 and 5) is further enhanced by the electron-withdrawing effect of the p-nitrophenyl substituent, as discussed above. In addition to these effects, it has been found that azomethine ylides that are sterically incapable of the symmetry-allowed[3] conrotatory ring closure are thermally stable to intramolecular cyclization. Conversely, the aziridine precursors to such ylides (e.g., 7[1d] and 8[2c]) are very resistant to thermolytic cleavage, since a concerted ring opening



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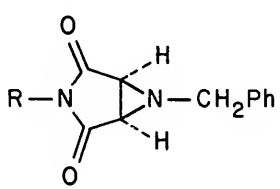

8

R = p-anisyl

would require the same difficult conrotatory motion. Finally, it might be expected that the steric* demands of substituents on the nitrogen atom of the azomethine ylide should affect the propensity for intramolecular

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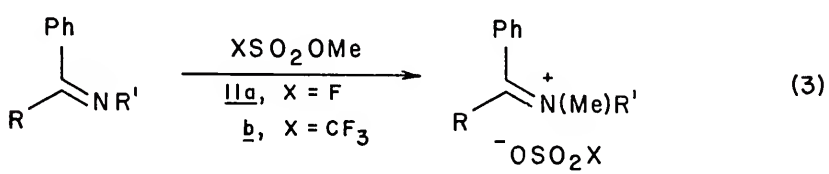
*Since the azomethine ylides are isoelectronic with the allyl anion, and since the highest occupied molecular orbital of the latter has a node at the central atom, it has been suggested (reference 5a) that small differences in the electronic characteristics of substituents on the nitrogen atom of the ylides should have little effect on the frontier-orbital energies of their dipolar termini.

cyclization. It can be argued, for example, that bulky substituents that encounter severe steric interactions with functional groups on either (or both) of the dipolar termini should force the termini together, resulting in a more facile closure to the aziridine. Indeed, it has been postulated[5] that even linear 1,3-dipoles (e.g., nitrile ylides) are bent in their transition states for cycloaddition reactions, ostensibly so that p-orbital overlap of the dipolar termini with the appropriate orbitals of the dipolarophile is maximized.

In view of the above considerations, ternary iminium salts of type 12-15 were reasoned to be likely precursors of azomethine ylides which would undergo the facile valence-bond isomerization to form aziridines. The reactivity of the derived 1,3-dipoles should be assured by the phenyl-substituted terminus and, perhaps, by bulky substituents (R' in equation 3) on the nitrogen atom. The problem of enamine formation (vide supra) would be obviated. The ketiminium salts 12 and 13 and the aldiminium salts 14 and 15 offered the potential to observe any substituent



(3)

9, R = Ph

10, R = H

12, R = Ph; X = F

13, R = Ph; X = CF_3

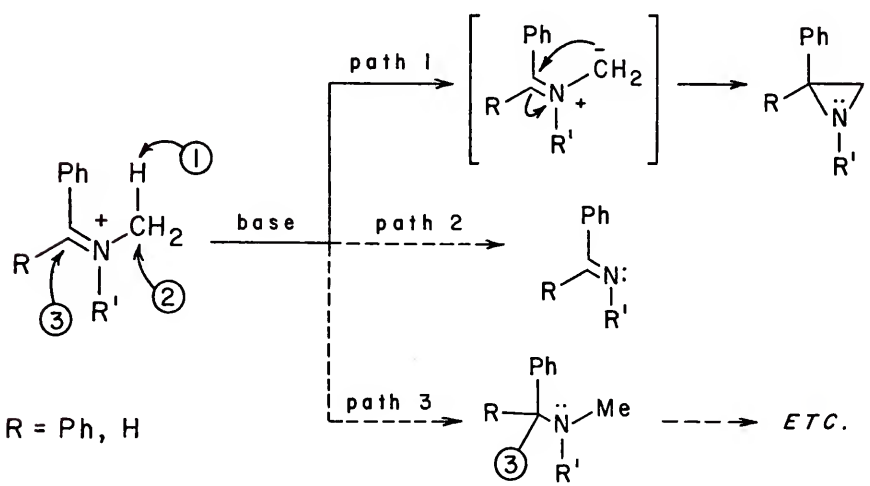
14, R = H; X = F

15, R = H; X = CF_3

effects on the outcome of the deprotonation reactions. Finally, the fluorosulfonate and trifluoromethanesulfonate (or "triflate") anions were chosen because of their extremely low nucleophilicities.[6] These anions could be incorporated into the iminium salts by alkylating imines 9 and 10 with methyl fluorosulfonate (11a)[7] or methyl triflate (11b).[8] These powerful alkylating agents are available commercially, and the imine precursors are readily accessible.

The problem that remained, then, was one of selecting a base which was suitably non-nucleophilic that other reactions did not compete with the desired deprotonation (path 1 in Scheme I). For example, the base could act via

Scheme I



16

path 2 to produce the dealkylated imine, or it might add to the electrophilic iminium salt (path 3) to produce adduct 16, which could react further under the reaction conditions. With the recent availability of strong, proton-specific bases,[9] the experimental problem at this point would be one of finding the most efficient base for the purpose described.

Ketiminium Salts

Results

A variety of ketimines (9) were prepared by slight modification of the method of Moretti and Torre,[10] as shown in equation 4. A solution of benzophenone in dichloromethane was stirred with a tenfold excess of the

$$Ph_2C{=}O + R'NH_2 \xrightarrow[CH_2Cl_2]{TiCl_4} Ph_2C{=}NR' \qquad (4)$$

9

$$Ph_2C{=}NR' \xrightarrow[\text{solvent}]{XSO_2OMe} Ph_2C{=}\overset{+}{N}(Me)R' \; {}^{-}OSO_2X \qquad (5)$$

9 ; X = F, CF_3

12, X = F

13, X = CF_3

appropriate primary amines, in the presence of titanium tetrachloride. As shown in Table I, the products were isolated in about 65-95% yield. Alkylation of the ketimines with methyl fluorosulfonate and methyl triflate afforded the corresponding N-methyl ketiminium salts 12 and 13, respectively. The results of the alkylation experiments are also presented in Table I. For example, the representative compound 12a is a white solid that can be recrystallized from absolute ethanol. Although it is slowly decomposed by atmospheric moisture over a period of several days, it can be stored in a drybox for several months without appreciable decomposition. This salt is relatively insoluble in hexane, carbon tetrachloride, benzene, ether, and chloroform. It is readily soluble, however, in polar solvents such as hexamethylphosphoramide (HMPA), acetone, dimethyl sulfoxide (DMSO), and liquid sulfur dioxide. Its nmr spectrum, taken in the latter solvent, shows a methyl resonance (δ3.86) which is deshielded by 43 Hz with respect to that of N-(benzhydrylidene)methylamine (9b). This downfield shift can be attributed to the inductive effect of the positively charged nitrogen atom of 12a on the methyl protons. Olah and Kreienbühl[11] have reported similar chemical shifts for related, protonated ketimines.

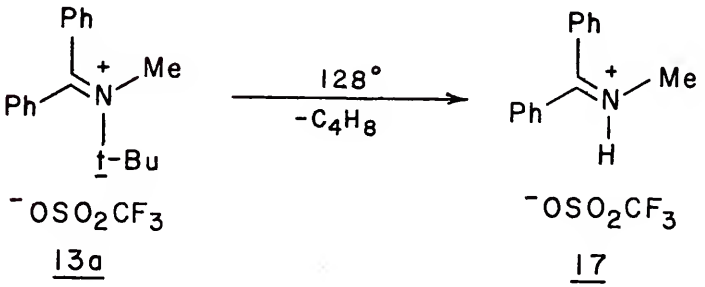
Interestingly, the triflate salt 13a decomposes at 128° with the liberation of a gas, presumably isobutene, as shown in equation 6. The crystalline residue was assigned

Table I. Ketimines and Ketiminium Salts

$Ph_2C=NR'$			$[Ph_2C=N(Me)R'](OSO_2X)$				
R'	Compd	Yield (%)	Compd	X	Alkylation solvent	Yield (%)	NMR SPECTRUM[a]
t-Bu	9a	93	12a	F	ether	97	1
t-Bu			13a	CF_3	$CHCl_3$	100	-
Me	9b	96	12b	F	ether	100	2
allyl	9c	93	12c	F	ether	98	3
$CHPh_2$	9d	63	12d	F	$CHCl_3$	68	4
Ph	9e	81	12e	F	ether	96	5

[a]All nmr spectra are presented in the section which begins on p 131.

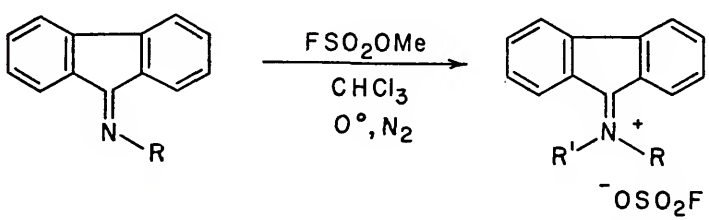
structure 17, based on the deshielded methyl singlet (δ3.47) in its nmr spectrum, and the conspicuous absence



13a 17 (6)

of a tert-butyl resonance.

A limit to the success of the alkylation procedure is indicated by two other experiments. Whereas alkylation of 18a with methyl fluorosulfonate proceeds within ten minutes to afford the expected product (19a) in 92% yield, attempts to methylate the corresponding tert-butyl deriva-



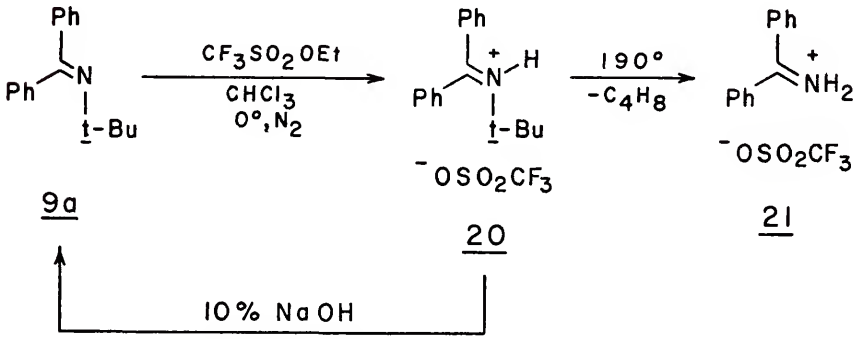
18a, R = Me
b, R = t-Bu

19a, R = R' = Me
b, R = t-Bu; R' = H (7)

tive (18b) under the same reaction conditions resulted only in the isolation of 19b, in 6% of the theoretical yield (based on 18b). More 19b was recovered after storing the reaction filtrate in a refrigerator overnight. Similarly,

whereas ketimine 9a is readily alkylated with methyl triflate, treatment with ethyl triflate affords only the protonated salt 20 (NMR SPECTRUM 6), as shown in Scheme II. The yield of 20 after 48 hours, however, was only 18%.*

Scheme II



Compound 20 suffered loss of isobutene on pyrolysis, to produce the primary iminium salt 21 in quantitative yield. In addition, 20 was readily deprotonated by aqueous sodium hydroxide to return the parent ketimine 9a. It seems unlikely that these protonations occur by an alkylation-elimination process, because it is difficult to explain why the lower-alkyl substituents should be eliminated in

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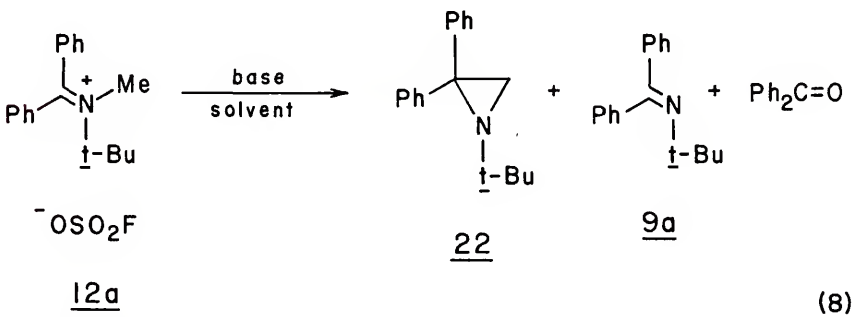
*In related cases, recall that the classical Decker amine synthesis (reference 12) fails when imine alkylation is attempted with substituents larger than methyl; also, Ford (reference 13) has recently reported the resistance of two highly hindered amines to alkylation with fluorosulfonates larger than the methyl ester.

preference to the tert-butyl group. It is more probable that large steric demands by substituents on either terminus of the C=N (e.g., the necessarily planar fluorene moiety and the N-tert-butyl group) seriously inhibit alkylation, and that the proton source is the acid which is slowly produced when traces of moisture in the system hydrolyze the alkylating agents.

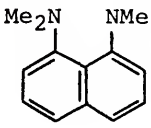
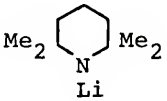
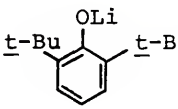
With the availability of the ketiminium salts listed in Table I, the problem of deprotonation was confronted. Using 12a as a model compound, it was found that treatment with a variety of bases did, in fact, produce the desired aziridine, compound 22. Inevitably, however, 22 was contaminated with varying amounts of the nucleophilically displaced product 9a and benzophenone, as indicated in equation



12a 22 9a (8)

8. The experimental conditions and the results of various deprotonations are summarized in Table II. These reactions were performed by adding the appropriate solvent to a stirring mixture of the iminium salt and a slight molar excess of the base, at various temperatures. The lithium

Table II. Aziridine:Imine (22:9a) Distribution Obtained from the Reaction of $[Ph_2C{=}N(Me)t\text{-}Bu](OSO_2F)$ (12a) with Various Base-Solvent Combinations

Base	Compd	Ref	Solvent(s)	T_o[a]	22:9a[b]
n-BuLi	23		ether-hexane	25	0[c]
	24	20	ether	-78	(n.r.)
	25	9a	ether-hexane	25	~0.7
	26		ether-hexane	-78	1[d]
$NaCH_2S(O)Me$	27	60	DMSO[e]	25	2
KO-t-Bu	28	61	HMPA[e]	0	0.4
			ether	-78	13
$KOCEt_3$	29	62	xylene	25	13
$NaN(SiMe_3)_2$	30	14	SO_2	-78	0
			DMSO[e]	25	11
			ether	25	16
			benzene	25	18
			hexane	25	22

[a]Initial reaction temperature, °C. [b]Mole-%, by nmr spectral assay. [c]Little, if any, 22 detected. [d]Recovered 70% of the iminium salt. [e]Homogeneous mixture.

bases 25 and 26 were prepared *in situ* from commercial *n*-butyllithium (23) in hexane. All deprotonations were carried out in an atmosphere of dry nitrogen. Almost invariably, a transient, deep red color was observed as the solvent was added to the salt-base mixture. The system was stirred at room temperature for one hour, and was then filtered. The filtrate was concentrated *in vacuo*, and the residue was assayed by careful integration of its nmr spectrum (for an example, see NMR SPECTRUM 11).

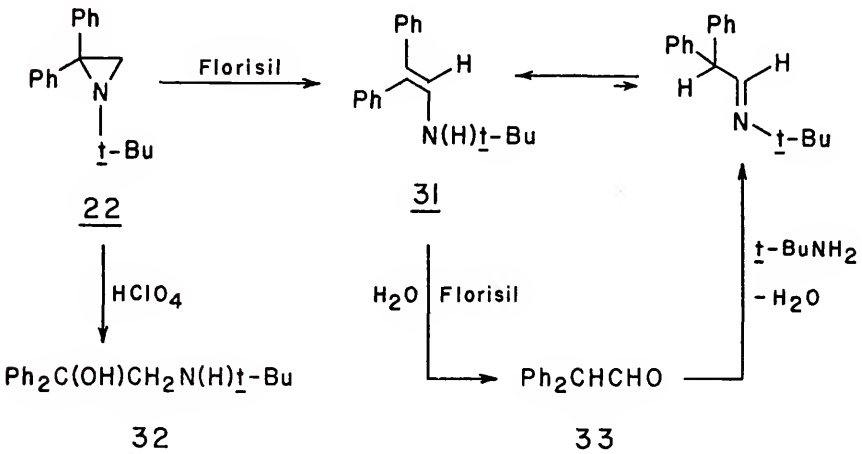
It is evident from the data in Table II that the most efficient base investigated in this study was sodium bis-(trimethylsilyl)amide, compound 30. This base is conveniently prepared in 85-95% yield by refluxing the inexpensive, commercially available hexamethyldisilazane with sodium amide in benzene, according to the method of Krüger and Niederprüm.[14] The base is soluble in a variety of organic solvents (*e.g.*, ether, benzene, xylene, HMPA, and DMSO). It was found that solutions of 30 in benzene could be readily assayed by titrating the sodium hydroxide that remained when the solutions were decomposed with boiling water:

$$\underset{30}{NaN(SiMe_3)_2} + 3H_2O \xrightarrow{\Delta} 2Me_3SiOH(g) + NH_3(g) + NaOH \qquad (9)$$

Considering the very high material balance and favorable product distribution which resulted when base 30 was used in hexane, 1-*tert*-butyl-2,2-diphenylaziridine (22) was synthesized in almost quantitative yield.

Aziridine 22 was identified by its spectral properties (see, for example, NMR SPECTRUM 12), and by the degradation experiments outlined in Scheme III. Passage of 22 through a column of Florisil afforded a mixture of the enamine 31

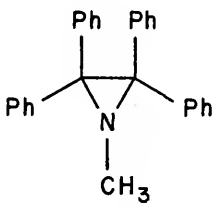
Scheme III



(NMR SPECTRUM 13) and its hydrolysis product, diphenylacetaldehyde (33). The structure of 31 was confirmed by synthesis from authentic 33 and tert-butylamine. The isomerization of 22 to 31 has precedent in the chemical literature,[15] as does the formation of alcohol 32 from 22.[16]

Disappointingly, none of the other ketiminium salts listed in Table I produced clean reactions upon treatment with sodium bis(trimethylsilyl)amide in benzene, although the reactions were invariably accompanied by intense color changes. For example, the physical characteristics and nmr

spectra of the crude mixtures obtained from ketiminium salts 12b and 12c indicated that gross polymerization had taken place. Benzophenone was the major product of the attempted deprotonation of the benzhydryl analog 12d. The nmr spectrum of the crude product mixture showed a singlet of low intensity at δ2.32, possibly due to one of the compounds 34, 35, or 36. The mixture was not characterized further. The methylanilinium fluorosulfonate 12e



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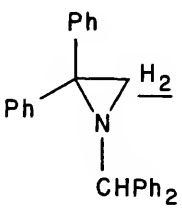

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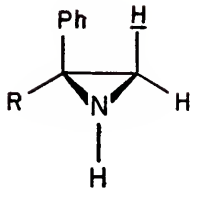
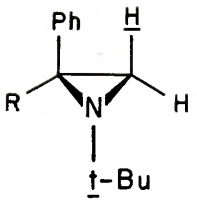
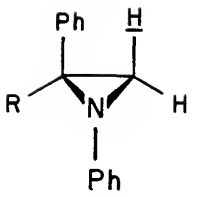
afforded a product mixture whose nmr spectrum indicated the presence of N-(benzhydrylidene)aniline (9e), N-methylaniline, and benzophenone. In addition, it is likely that a prominent singlet at δ2.77 belonged to the methylene protons of the expected (but unreported) aziridine 41: consider the deshielding effect of geminal diphenyl substitution on the chemical shifts of the indicated protons of compound 37 (δ0.93[17]) versus 38 (δ2.12[18]), and 39 (δ1.44[16]) versus 22 (δ2.16). By analogy, it is not unreasonable to expect that the methylene protons of compound 41 would resonate at least 0.4 ppm downfield from the indicated proton of compound 40 (δ2.34[19]). Unfortunately, all attempts







37, R = H
38, R = Ph

39, R = H
22, R = Ph

40, R = H
41, R = Ph

to isolate the supposed aziridine 41 by column chromatography, distillation, fractional crystallization at -78°, and perchlorate extraction were fruitless. Somewhat surprisingly, the latter technique returned N-methylaniline as the only extractable basic product.

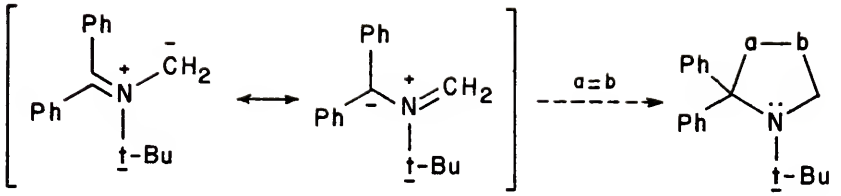
Discussion

It is difficult to discern trends in the product ratios listed in Table II as a function of the bases and solvents used. It appears that the necessary conditions for the high conversion of 12a to aziridine 22 are the use of a strong, hindered base under heterogeneous, anhydrous conditions.

Thus, whereas 1,8-bis(dimethylamino)naphthalene (24)[20] is a hindered base, it is a relatively weak one (pK_a 12.34[20]). Whereas n-butyllithium (23) is a very strong base, it is probably not hindered enough to be selective. Furthermore, it is known[21] that the thermal and photochemical generation of certain azomethine ylides from aziridines is highly

solvent dependent. In the present study, it appears that nonpolar solvents and heterogeneous reaction conditions gave the best results. An alternative to this solvent-effect explanation is the possibility that rigorous exclusion of moisture is necessary for favorable product distributions. Although traces of moisture in the mixture were shown to have little direct effect on the integrity of the ketiminium salt, the bases used in this study are extremely susceptible to hydrolysis. The products of hydrolysis (alkali-metal hydroxides) might then be responsible for less-favorable product ratios, as well as for the production of benzophenone. Evidence for this possibility was the observation that the hygroscopic solvents, ether and DMSO, produced lower yields of the aziridine using the silylamide base than did the hydrophobic solvent, hexane. In addition, the reaction in hexane produced only a very small quantity of benzophenone.

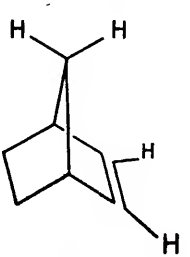
Although it is tempting (and not unreasonable[21]) to speculate that the transient color observed in the deprotonation of 12a was due to the azomethine ylide 42, there was no direct evidence that this was the case. Attempts to trap 42 with conventional dipolarophiles (equation 10) were unsuccessful. A major experimental problem was the instability of most of the trapping agents tried (e.g., dimethylacetylenedicarboxylate, benzaldehyde, and acetone) to the strong bases. Norbornene (43), on the other hand, failed to react with anything under the reaction conditions



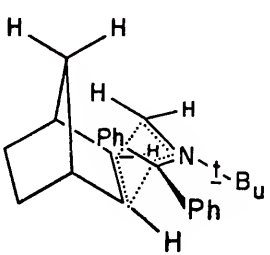
42

(10)

of 12a and $NaN(SiMe_3)_2$ in benzene at 25°. Of course, as Padwa and Hamilton have demonstrated,[21] failure to trap the postulated ylide does not nullify the possibility of its intermediacy. Rather, this result may simply be



43



44

attributed to the low steady-state concentration of a highly reactive species. Alternatively, it is known that steric factors can affect the rates[1d] and regioselectivities[2i,5b] of dipolar cycloadditions. It can easily be appreciated by inspection of geometry 44 that the most probable[1e] transition state for the cycloaddition of 42 to norbornene might be sufficiently crowded that this reaction can not

compete effectively with intramolecular closure of the azomethine ylide.

Based on the experimental data which are available, it is not possible to explain the different results that were obtained for the tert-butyl ketiminium salt vis-à-vis the other derivatives. The complexities associated with two-phase reactions, and the fact that reaction conditions were not optimized for salts other than 12a, make any such rationalizations purely speculative.

Aldiminium Salts

Results

It was found that aldimines (10) could also be prepared and smoothly alkylated with methyl fluorosulfonate,

$$\mathrm{PhCHO} + \mathrm{R'NH_2} \xrightarrow[-\mathrm{H_2O}]{\Delta} \underset{\underline{10}}{\mathrm{PhCH{=}NR'}} \qquad (11)$$

$$\underset{\underline{10}}{\mathrm{PhCH{=}NR'}} \xrightarrow[\text{ether}\ -78^\circ,\ \mathrm{N_2}]{\mathrm{FSO_2OMe}} \underset{\underline{14}}{\mathrm{PhCH{=}\overset{+}{N}(Me)R'\ {}^-OSO_2F}} \qquad (12)$$

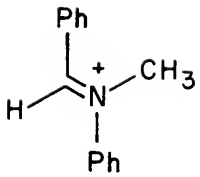
to afford the corresponding aldiminium salts 14 in high yield (equations 11 and 12), as summarized in Table III. The alkylations were effected in ether at low temperature, and the crude products were isolated as white solids having

Table III. Aldimines and Aldiminium Salts

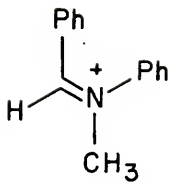
	PhCH=NR'		[PhCH=N(Me)R'](OSO$_2$F)		
R'	Compd	Yield (%)	Compd	Yield (%)	NMR SPECTRUM
t-Bu	10a	95	14a	99	7
Me	10b	95	14b	96	8
allyl	10c	79	14c	99	9
CH_2Ph	10d	100	14d	-	-
Ph	10e	84	14e	98	10

broad melting ranges. An exception was 14d, which was isolated as an oil. Unlike the ketiminium salts, the alkylated aldimines are very hygroscopic, and had to be synthesized and manipulated in a nitrogen-purged drybox.

The nmr spectra of several of the aldiminium salts, taken in liquid sulfur dioxide, clearly indicate a mixture of entgegen and zusammen isomers. For example, NMR SPECTRUM 10 of compound 14e shows a 4:1 mixture, with the upfield methyl resonance belonging to the major isomer. From steric considerations alone, one would predict the major isomer to be 45a, with its more favorable disposition of aromatic rings, relative to 45b. Indeed, NMR SPECTRUM 7 of the tert-butyl derivative (14a) indicates almost exclusively a single isomer, presumably also the entgegen isomer. In addition, the slightly higher chemical shift of the methyl doublet belonging to the major isomer of 45 can be attributed to shielding by the proximate C-phenyl substituent



45a

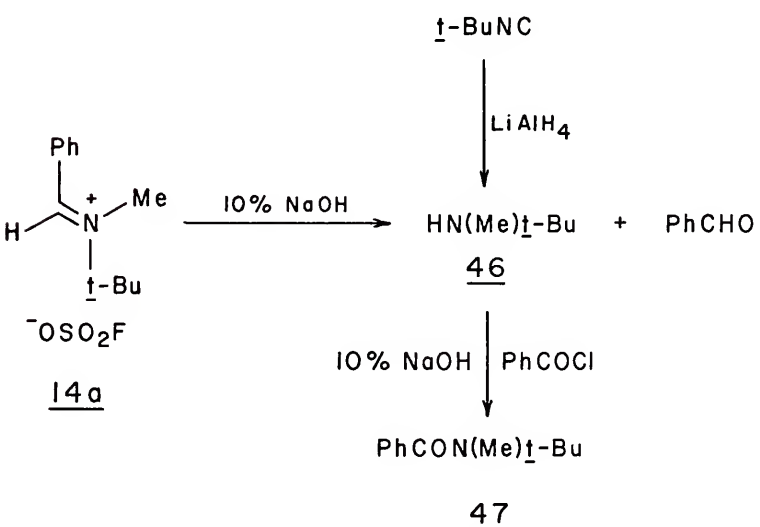


45b

of isomer 45a. Keenan and Leonard[22] have made the same assignment for the methyl substituents of a closely related iminium salt.

As chemical proof of the structure of these salts, compound 14a was subjected to basic hydrolysis as shown in Scheme IV, and the resulting amine was scavenged with

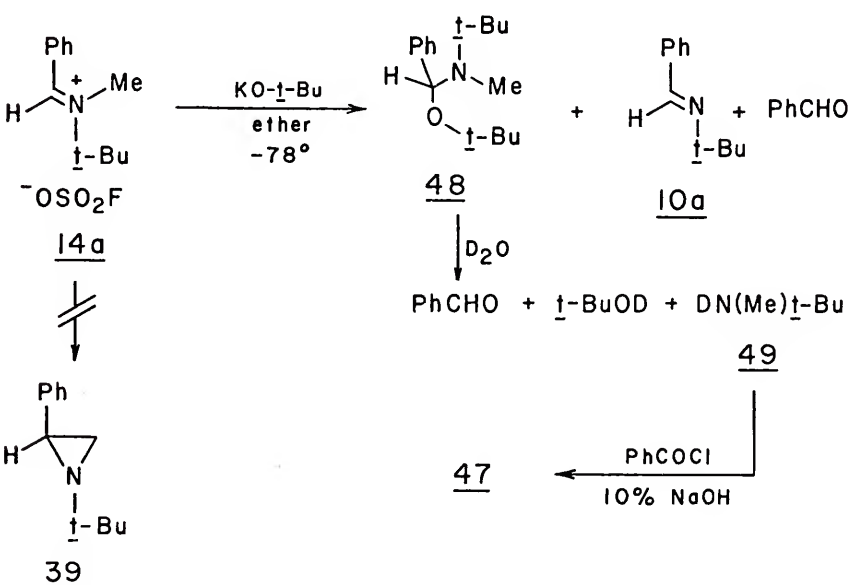
Scheme IV



benzoyl chloride. The product was amide 47 (NMR SPECTRUM 14). The same amide was produced by similar derivatization of authentic methyl-tert-butylamine (46), prepared by reducing tert-butyl isocyanide with lithium aluminum hydride.[23]

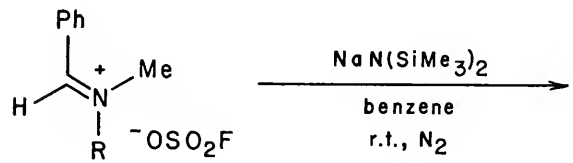
The results of the attempted deprotonation of 14a with a slight excess of potassium tert-butoxide in ether are shown in Scheme V. It was demonstrated that the expected aziridine 39 was not a component of the crude reaction mixture, by comparing the tlc behavior and spectral properties of the mixture with those of authentic[16] 39. Instead, 80% of the crude reaction product consisted of the aminoether 48, accompanied by the demethylated

Scheme V

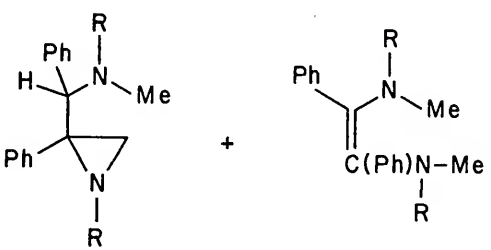


product 10a (12%) and benzaldehyde (5%).* Compound 48, formally derived from the direct addition of tert-butoxide to the aldiminium salt, was purified by distillation and identified by its spectral properties (see, for example, NMR SPECTRUM 15). In addition, a facile deuterolysis converted 48 to equimolar quantities of benzaldehyde, deuterio-tert-butanol, and amine 49 (Scheme V). The latter compound was characterized as its benzamide derivative, 47.

Treatment of the aldiminium salts 14a and 14b with sodium bis(trimethylsilyl)amide in benzene produced the



14a, R = t-Bu
b, R = Me



(13)

50, R = t-Bu
51, R = Me

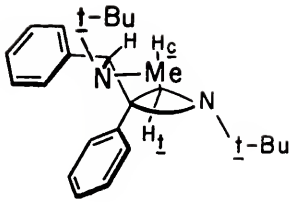
52, R = t-Bu
53, R = Me

*The dimers 50 and 52 (vide infra) were also produced in this reaction, to the combined extent of 3% of the product mixture.

unexpected results indicated by equation 13. Again, aziridine 39 was conspicuously absent from the product mixture. The structure of product 50 was assigned on the basis of spectral and chemical evidence. It was possible, for example, to isolate both diastereoisomers of 50 by careful silica gel chromatography of the crude product mixture. The major and minor isomers (5:1 in the crude mixture) were assigned the relative configurations* 50a and 50b, respectively. The structures are drawn in their most probable conformations, from consideration of molecular models. The assignments are based on the nmr data given in Table IV (from NMR SPECTRUM 16 of the major isomer and NMR SPECTRUM 17 of the minor isomer), and the arguments which follow:

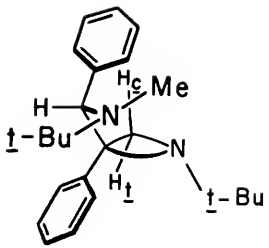
(1) The prochiral H_t protons of the two isomers are in similar stereochemical environments and, therefore, should have similar chemical shifts. In the absence of a suitable model compound, one can not say with certainty which of the two doublets in the spectrum of the major isomer belongs to H_t, due to their similar chemical shifts. However, one can assign the downfield doublet of the minor isomer to H_t, because its chemical shift (δ1.68) is closest to that of H_t of the major isomer (δ1.74 or δ1.98). The

*The possibility that the isomers are conformational (rotational) diastereoisomers has not been excluded. However, the high barrier to rotation that would be necessary to enable isolation of such isomers seems unlikely.



MAJOR ISOMER

50a



MINOR ISOMER

50b

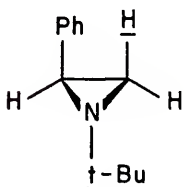
Table IV. Nmr Spectral Assignments for the Diastereoisomers of Compound 50

Assignment	Chemical Shift (δ,CCl_4) Major Isomer	Minor Isomer
$-C(CH_3)_3$	0.71 and 0.89	0.77 and 0.83
$-H_c$[a]	1.74 or 1.98	1.13
$-H_t$	1.98 or 1.74	1.68
$N-CH_3$	2.33	2.78
$Ph-CH$	4.48	4.13
$-C_6H_5$	7.0 to 7.5	7.0 to 7.5

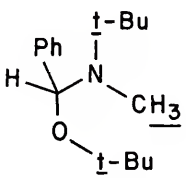
[a] H_c is the hydrogen atom which is on the same face of the plane defined by the aziridine ring as the aminomethyl side chain. The other methylene proton, then, is H_t.

upfield doublet (δ1.13), then, must belong to H_c of the minor isomer. Compared to the other aziridine protons, and to the indicated proton in model compound 39 (δ1.44), H_c in the minor isomer is fairly shielded. Inspection of conformation 50b suggests that this effect may be induced by the aromatic ring on the aminomethyl side chain of the proposed minor isomer.

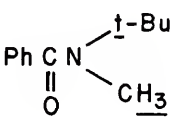
(2) The same aromatic ring in 50b which shields H_c



39



48



47

is oriented in such a way that it deshields the N-methyl protons of the minor isomer. Note that these protons (δ2.78) are, in fact, deshielded: cf. the methyl protons of amine 48 (δ2.21, NMR SPECTRUM 15) and amide 47 (δ2.75, NMR SPECTRUM 14).

(3) The shielding of the methine proton of the minor isomer vis-à-vis the major isomer is probably the result of the position of this proton with respect to the shielding zone of the phenyl group on the aziridine ring, a feature which is not present in 50a.

A more definitive assignment of relative configuration must await X-ray analysis.

As chemical proof of structure, it was demonstrated that both of the isomers of 50 could be converted to diaminostilbene 52 (*vide infra*) by thermolysis in a sealed capillary at 250°.

Although product 51 decomposed on several attempts to purify it, its presence in the product mixture obtained from iminium salt 14b was deduced by spectral analogy with the major *tert*-butyl isomer, 50a.

In addition to 51, a mixture of *E*- and *Z*-diaminostilbenes 53a and 53b (NMR SPECTRUM 18) was produced in the reaction of 14b with sodium bis(trimethylsilyl)amide. The structures of these isomers were confirmed by synthesis of a mixture of the authentic compounds, according to the method of Scheeren and van Helvoort.[24] The synthesis, shown in Scheme VI, produces approximately equal quantities

Scheme VI

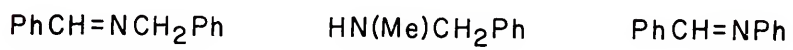
53a 53b

of 53a and 53b, as does the deprotonation reaction of iminium salt 14b. The complete separation of E- and Z-isomers was not effected. However, the nmr spectra of various chromatographic fractions revealed that the singlets at δ2.28 and δ7.18 belong to one isomer, and those at δ2.69 and δ6.88 belong to the other. If one assumes that the canted aromatic rings shield the methyl protons of only the entgegen isomer (the methyl protons of the zusammen isomer are not within the shielding zone of the aromatic substituents), the upfield methyl singlet can be assigned to isomer 53a. The chemical shift of this resonance corresponds almost exactly to that of the methyl resonance of the single diaminostilbene (52) which is produced from the tert-butyl aldiminium salt, 14a (see NMR SPECTRUM 19). Compound 52, then, is also assigned the entgegen configuration. Of course, this assignment is reasonable on the basis of steric considerations, too.

Interestingly, although treatment of the aldiminium salts 14a and 14b with $NaN(SiMe_3)_2$ produced analogous products, the product distribution was markedly different. Whereas the tert-butyl derivative afforded about nine times as much of the aminomethylaziridine isomers 50 as the diaminostilbene 52, the crude product mixture obtained from the dimethyl derivative contained approximately equal proportions of 51 and 53.

Treatment of the three other aldiminium salts with sodium bis(trimethylsilyl)amide in benzene produced complex

mixtures. Products corresponding to 50 and 52 could not be isolated from the mixtures, if, in fact, they were present. For example, the N-allyl salt (14c) yielded a mixture which, after column chromatography under the same conditions that enabled the separation of 52 and the isomers of 50, afforded benzaldehyde as the only identifiable product. Treatment of the N-benzyl derivative 14d with the silylamide base produced 10d and 54 in small amounts. No other component of the crude reaction mixture was identified. The structure of 54 was confirmed by



10d 54 10e

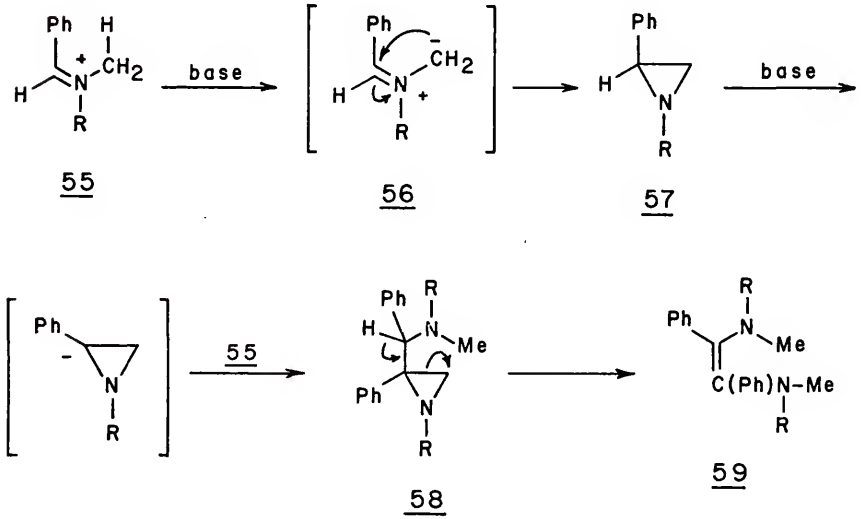
isolation of the compound via perchloric acid extraction, and comparison of the ir and nmr spectra of the product with those of authentic methylbenzylamine.[25] Note that the course of this deprotonation may have been altered by the relatively impure state of the starting material: 14d was isolated as an oil, which could not be crystallized. N-(Benzylidene)methylanilinium fluorosulfonate (14e) produced a dark, viscous syrup upon treatment with $NaN(SiMe_3)_2$. The mixture was shown by nmr spectral analysis to contain several silylated species and N-(benzylidene)aniline, 10e. In addition, there were several unidentified singlets in the spectrum in the region 2.6-2.9 ppm.

Discussion

A priori, formation of the reaction products obtained by treating the aldiminium salts 14a and 14b with sodium bis(trimethylsilyl)amide can be explained by at least three mechanisms. According to the first, which will be arbitrarily labeled Mechanism A (Scheme VII), abstraction of an aldiminium methyl proton by the base, followed by intramolecular cyclization of the resulting azomethine

Scheme VII

MECHANISM A



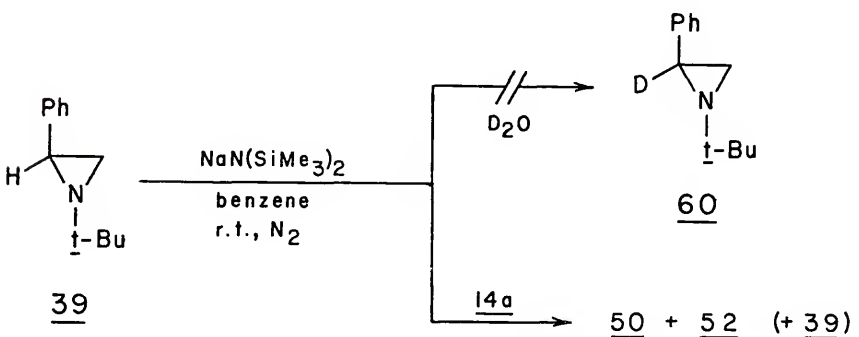
R = t-Bu, Me

ylide (56), would produce aziridine 57, in a manner which is exactly analogous to the reaction of the N-tert-butyl

ketiminium salt (vide supra). Although the abstraction of a proton on an aziridine ring is known to be a difficult process,[26] it is conceivable that deprotonation of 57 would produce an aziridinyl anion, which could condense with another molecule of the aldiminium salt. The product would be the observed aminomethylaziridine, 58. Proton transfer (presumably stepwise) would afford the diaminostilbene, 59.

To test Mechanism A for the case R=t-Bu, the known[16] aziridine 39 was treated with the silylamide base in benzene. As depicted in Scheme VIII, addition of deuterium oxide after one hour failed to produce the deuterium-exchanged product 60 (as evidenced by nmr spectroscopy). Similarly,

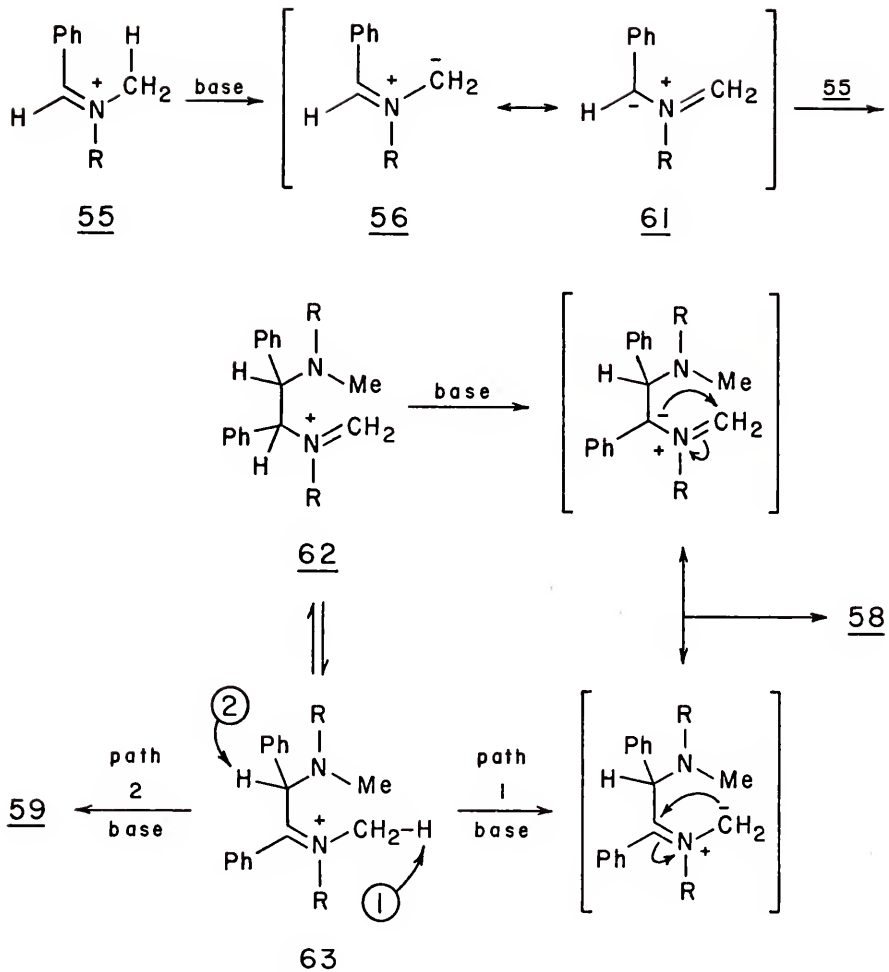
Scheme VIII



inclusion of 39 in the reaction mixture of the aldiminium salt 14a, base, and benzene, afforded only the "normal" reaction products. Aziridine 39 was recovered intact. Finally, it was shown that the major isomer of the amino-methylaziridine 50 could be recovered unchanged, after

Scheme IX

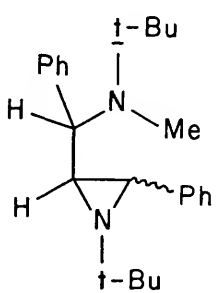
MECHANISM B



R = t-Bu, Me

stirring it with the base in benzene at room temperature. In particular, there was no evidence for the conversion of major-50 to 52, the last step in the proposed Mechanism A.

According to the second mechanism, outlined in Scheme IX, the resonance-stabilized azomethine ylide 56 would be generated, as per Mechanism A. However, since it is not unreasonable to expect that the carbon terminus of the ylide bearing the phenyl group should have the greatest anionic character, it is conceivable that reaction of the ylide (as 61) with 55 would produce intermediate 62. Deprotonation of 62, or initial tautomerization followed by deprotonation via paths 1 and 2, would afford the observed products. A somewhat disturbing aspect of Mechanism B is the unlikelihood that the initial intermediate would react exclusively in the canonical form 61. Indeed, steric factors favor form 56, with its less-hindered reactive terminus, and it is well known that steric effects can overwhelm electronic



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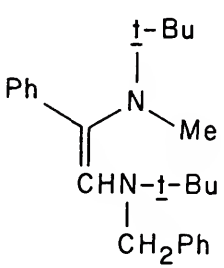


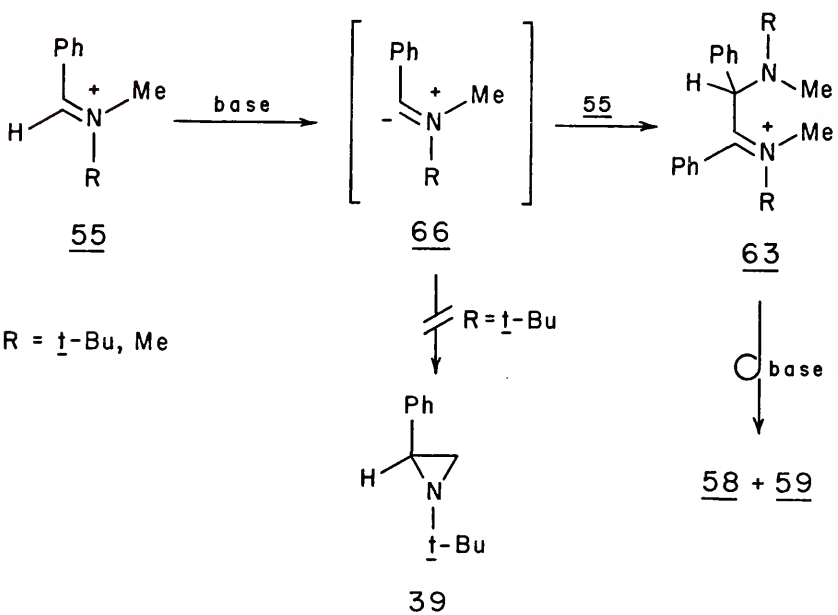
65

preferences for regioisomeric transition states.[2i,5b] However, resonances which could be attributed to 64 and 65, derived from the condensation of 56 with salt 12a (assuming Mechanism B), were not detected in the nmr spectrum of the crude product mixture. In addition, it is difficult to explain the failure of 12a to cyclize to aziridine 39 after deprotonation, if this second mechanism were operating.

Mechanism C, then, postulates initial abstraction of the vinylic proton of 55 to afford the azavinylic anion 66, as indicated in Scheme X. There are many reports in

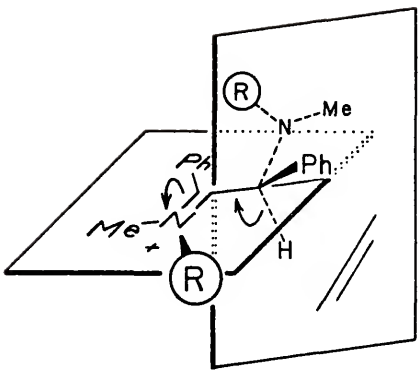
Scheme X

MECHANISM C



the literature which attest to the acidity of protons in related environments.[27] Nucleophilic attack by 66 on the iminium salt would produce intermediate 63, which is common to the preceding mechanism. As it was demonstrated, 63 can react to produce the observed products 58 and 59. Mechanism C offers an attractive explanation for the observation that aziridine 39 is not a product of the reaction of 12a with the base: as shown in Scheme X, 39 can not be formed directly from intermediate 66 (R=t-Bu). Furthermore, this last mechanism avoids the regioselectivity problem associated with Mechanism B.

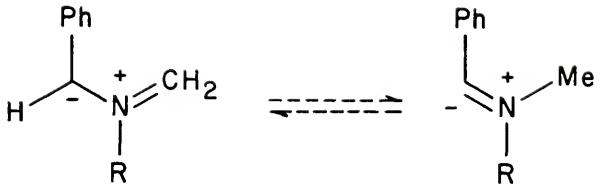
In both Mechanisms B and C, the common intermediate 63 can serve to account for the different product distributions obtained by deprotonation of the tert-butyl- versus the dimethyl-aldiminium salt. The methine proton of 63 is effectively acidic only when its bond to carbon lies in a plane which is orthogonal to the general plane of the iminium moiety (geometry 67). Since bulky R groups on both nitrogen atoms are likely to discourage such a geometry, due to steric interactions, reaction via path 1 (Scheme IX) should be more predominant for the case R=t-Bu than for the case of the less-hindered dimethyl intermediate (R=Me), which should more easily accommodate geometry 67 (and, hence, experience more favorable competition by path 2). The result would be a higher ratio of 58 to 59 for R=t-Bu than for R=Me, as observed. Note, too, that the disposition of the amine and phenyl substituents on the chiral carbon atom of 63 determines



67

whether the E- or the Z-diaminostilbene is produced: 67 has been drawn such that the former would result. From steric considerations, this disposition is less critical for R=Me than for R=t-Bu, since the latter intermediate must orient itself to minimize nonbonded interactions between tert-butyl groups. Thus, one would predict that 14b should produce a more equal distribution of E- and Z-isomers than would 14a. This last prediction was confirmed by experiment, too, as was described earlier.

The problem of differentiating experimentally between Mechanisms B and C is a difficult one. It is complicated by the potential interconversion of the initial intermediates in the two mechanisms (equation 14). As a result, success in demonstrating the intermediacy of either of

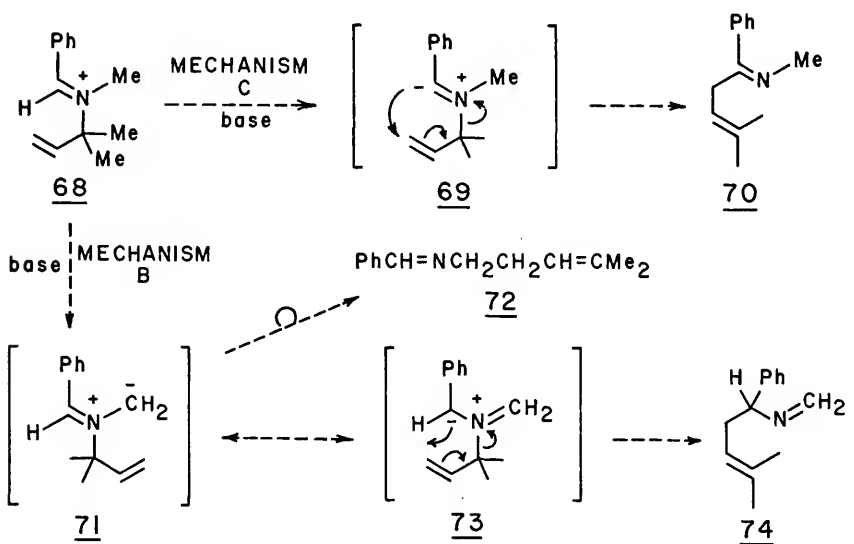


(14)

61 66

these species could not be construed as firm evidence for either of the two mechanisms.* However, a novel experiment which might lend support to one or the other of the mechanistic possibilities is proposed in Scheme XI. Consider

Scheme XI



*Norbornene was found to be ineffective as a trapping agent for any of the intermediates derived from salt 14a.

the deprotonation of the dimethylallyl salt 68, a reasonable steric and electronic approximation of the tert-butyl aldiminium salt. If Mechanism B were operating, abstraction of an N-methyl proton from 68 would provide intermediate 71. A thermally allowed [2,3] anionic sigmatropic rearrangement of either 71 or its resonance contributor, 73, would afford products 72 and 74, respectively. There is ample literature precedent for similar rearrangements.[28] Alternatively, the operation of Mechanism C would be suggested by the production of ketimine 70, the result of another rearrangement of the azavinylic anion 69. The starting material, compound 68, should be made available by methylating the imine derived from benzaldehyde and the appropriate allylamine.[29]

The origin of the asymmetric bias that produced the two diastereoisomers of aminomethylaziridine 50 is open to speculation, because the energy difference between two diastereomeric transition states is usually very small.* One argument for the supposed predominance of isomer 50a is outlined in Scheme XII. Assume that Mechanism C is operating. Attack by the azavinylic anion on the si-face of the iminium salt, for example,** would afford intermediate 75, having the rectus configuration. Deprotonation

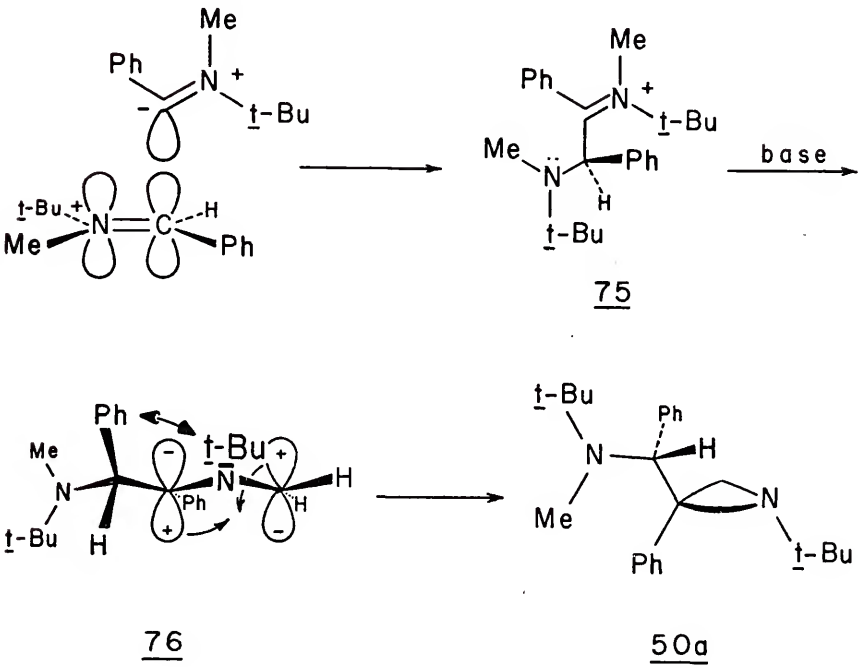
---

* For example, on the order of 0.1-5 kcal/mol for cycloaddition reactions; see reference 5b.

** Although attack on the re-face is equally probable, the eventual aminomethylaziridine is simply the enantiomer of 50a.

of 75 would produce azomethine ylide 76, which has been drawn in a probable conformation.[2i] Although there are

Scheme XII



two topologically distinct conrotatory modes of ring closure available to all electrocyclic transition states,[30] it is known that steric factors ("secondary orbital interactions") play a large part in determining the preferred mode. It is suggested that the conrotatory mode shown for 76 would predominate, to circumvent the steric

interaction of the dipolar tert-butyl substituent with the phenyl group on the aminomethyl side chain. The relative configuration of the product, 50a, would be the same as that assigned to the major diastereoisomer from nmr spectral considerations (vide supra). The opposite mode of conrotatory ring closure would provide the supposed minor isomer of 50.

The pyrolyses of both diastereoisomers of 50 to produce the same diaminostilbene (52) is, at least formally, the result of thermally allowed conrotatory ring openings to form the respective enantiomeric ylides 77a and 77b, followed by [1,4] anionic shifts of the methine protons, as shown in Scheme XIII. Chapman and Eian[31] have published a similar example of the latter process. The intermediacy of azomethine ylides 77a and 77b is supported by the experimental observation that pyrolysis of major-50 also produces some minor-50,* and vice versa. Since the thermolytic ring openings of aziridines are generally reversible processes (equation 1), it is certainly possible that one isomer of 50 could epimerize partly to the other via an ylide intermediate.

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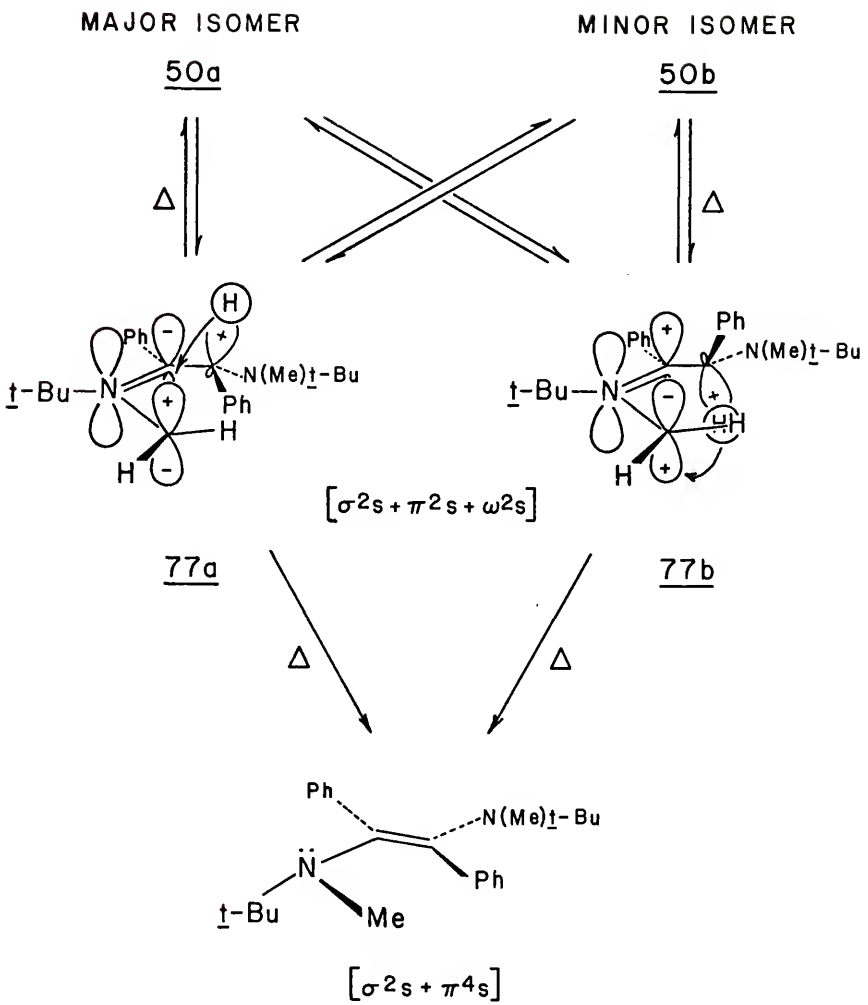
* More accurately, configuration 50a is converted to the enantiomer of configuration 50b (but still the minor isomer).

Scheme XIII



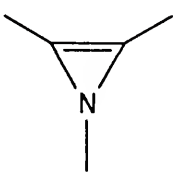
52

CHAPTER II

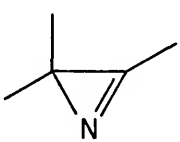
APPROACHES TO THE SYNTHESIS OF THE 2-AZIRINE SYSTEM

Introduction

Synthetic and theoretical chemists have long been fascinated by the 2-azirine system, 78. Despite claims for the intermediacy of 78 in mass spectral fragmentations[32] and chemical reactions,[33] and despite several spurious reports of the isolation of derivatives of 78,[34] the synthesis of an authentic 2-azirine has not been achieved.



78

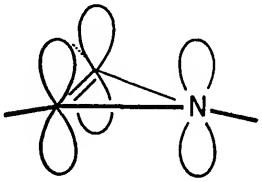


79

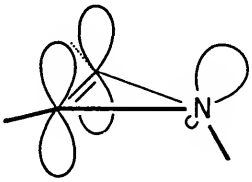
The failure to prepare a stable 2-azirine can not be attributed to inordinate strain within the molecule, since the isomeric 1-azirines (79) are well-known compounds.[35] Therefore, it seems likely that the alleged instability of 78 can be attributed to an unfavorable electronic situation. Indeed, theoretical interest in 2-azirines derives from the theory that they are potentially 4π-electron anti-Hückel

systems,[36] isoelectronic with the cyclopropenyl anion,[36a] which should be destabilized by cyclic conjugation. Simple Hückel molecular orbital calculations predict a destabilization energy of 0.30β for the parent 2-azirine, relative to its open-chain analog, enamine.[37]

In principle, there are two major geometries that the 2-azirine system can adopt. In one geometry, 80, the nonbonded electrons on the nitrogen atom occupy the unhybridized $2p_z$ orbital, resulting in a conformation in which the nitrogen substituent is coplanar with the three-membered ring. Alternatively, the predicted unfavorable electronic



80

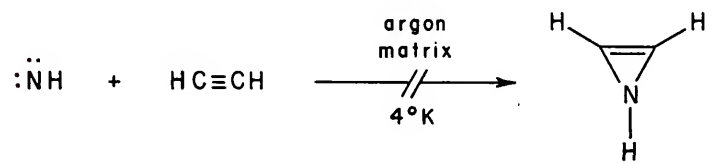


81

situation in 80 can be alleviated to some extent if the nitrogen atom assumes sp^3-hybridization, thereby minimizing interaction of the nonbonded electrons with the carbon-carbon π-system. This results in the nonplanar (and nonaromatic) conformation, 81. In addition to electronic considerations, the strained three-membered ring should more easily accommodate the sp^3-hybridized nitrogen atom of 81, with its smaller endocyclic valence angle. Recent calculations by Clark[38] predict that the nitrogen substituent

should deviate from the plane of the 2-azirine ring by 68°, and that the barrier to nitrogen inversion should be 35.14 kcal/mol. This sizable barrier ostensibly reflects the instability of the planar transition state for inversion, geometry 80. Clark's calculations have been substantiated recently by those of Dewar and Ramsden.[39]

The synthesis of the 2-azirine system has been attempted from two directions: (1) direct synthesis of the three-membered ring, and (2) modification of an intact three-membered ring. With regard to the first strategy, the most common approach has been via the addition of nitrenes to acetylenes. A relatively "early" (1963) application[40] of this approach involved the attempted matrix isolation of 82 by the addition of singlet nitrene



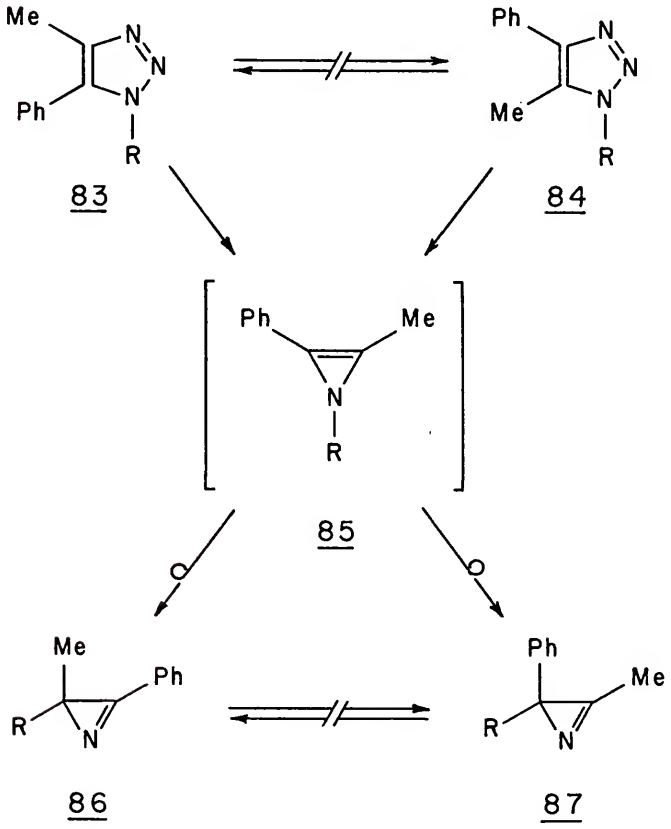
(15)

82

to acetylene, as shown in equation 15. The only product which was detected, however, was ketenimine ($H_2C=C=NH$). The intermediacy of a 2-azirine was first claimed by Rees and his colleagues, based on the nitrene approach.[33a,d] Other attempts[41] to add nitrenes to acetylenes have failed to produce evidence for the existence of 78.

More recent work from Rees' group,[33b,c,e] outlined in Scheme XIV, has provided the most convincing evidence for the intermediacy of the 2-azirine system to date. It was found that the same products and product ratios were

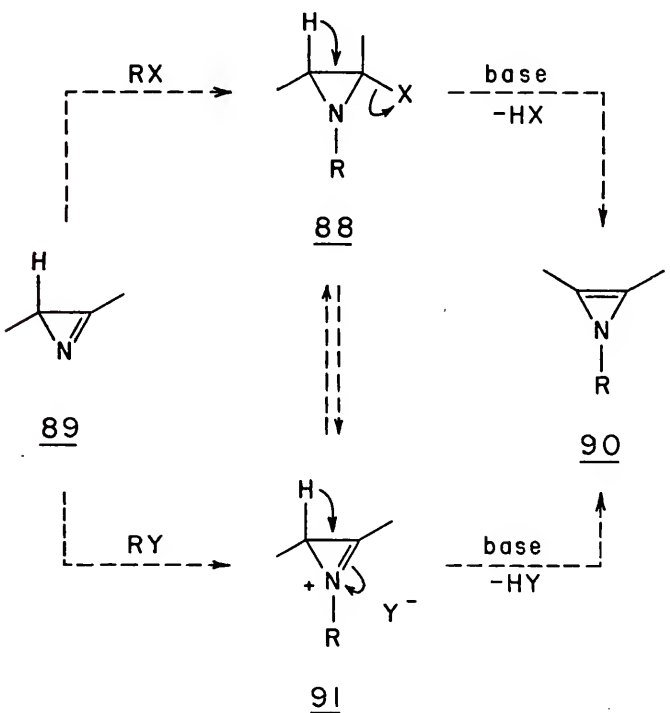
Scheme XIV



R = 2-phthalimido

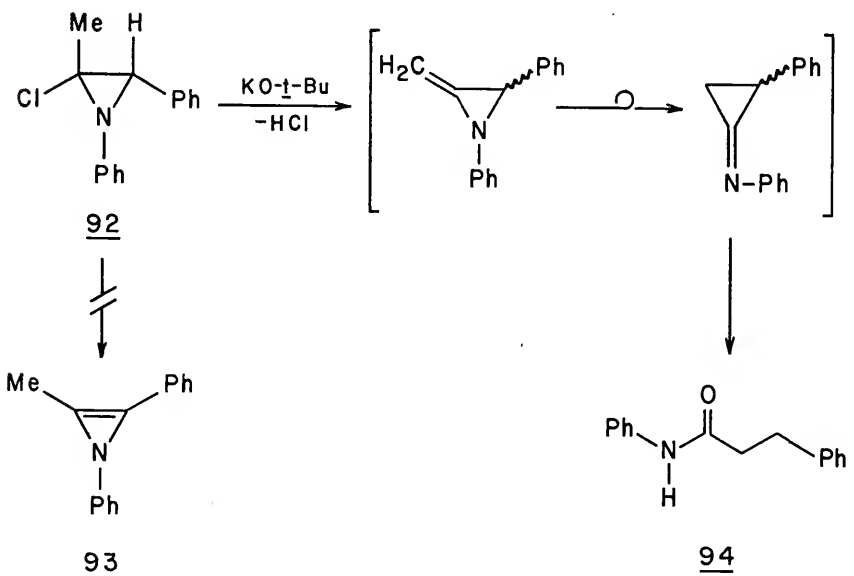
obtained by vapor-phase flash photolysis of the isomeric triazoles 83 and 84. Since it was demonstrated that there was no interconversion between the two starting materials, or between the products 86 and 87, a common intermediate was indicated. The authors assigned to this intermediate, structure 85. Related work on the triazole system by Burgess et al.[42] failed to produce evidence for a 2-azirine intermediate.

Scheme XV



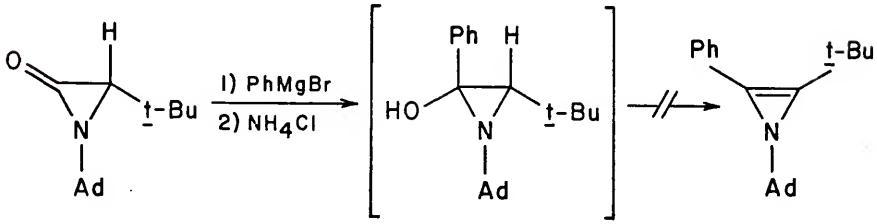
Synthetic approaches to the 2-azirine system that are based on modifying an existing three-membered ring are shown in Scheme XV. The strategy of using substituted aziridines (88) as potential 2-azirine precursors has been tried, for example, by Deyrup and Greenwald.[43] As outlined in Scheme XVI, treatment of 92 with potassium tert-butoxide afforded hydrocinnamanilide (94) as the major

Scheme XVI



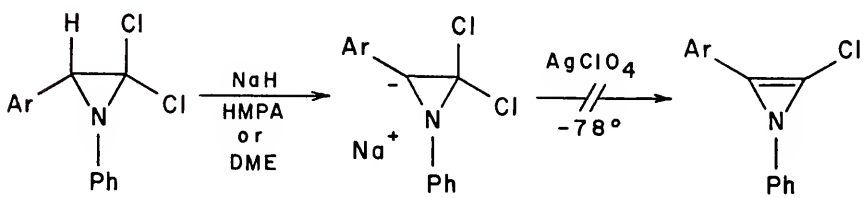
reaction product, the apparent result of a heteromethylenecyclopropane rearrangement. The authors found no evidence for compound 93. Similar approaches involving monochloroaziridines[37] and aziridine esters[44] have also been

unsuccessful in preparing the 2-azirine system, as has the sequence indicated in equation 16.[45] As a final example, Rubottom et al.[46] have recently reported the



(16)

Ad = 1-adamantyl



95 96

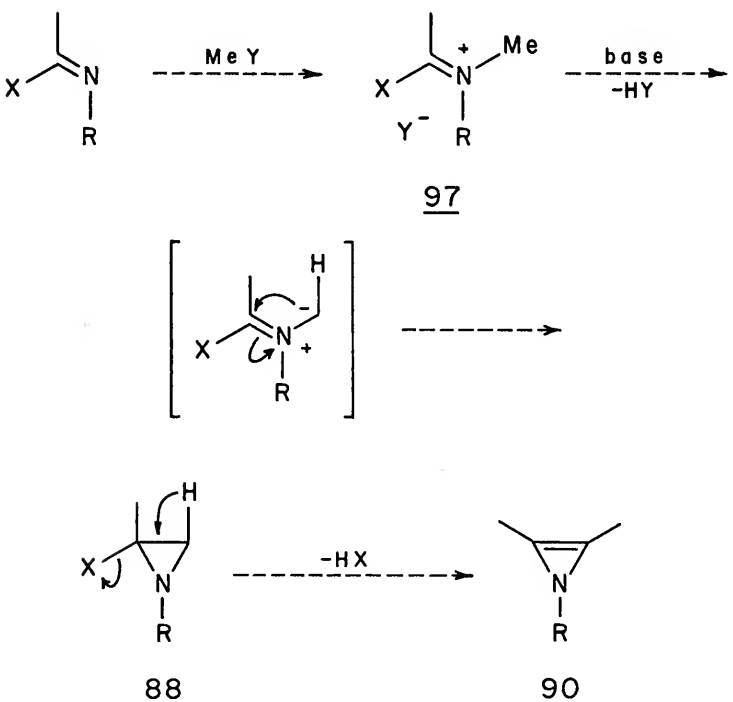
(17)

synthesis of a stable aziridinyl C-anion (95), which, instead of being converted to 96, produced a "living polymer"(!) upon treatment with silver perchlorate.

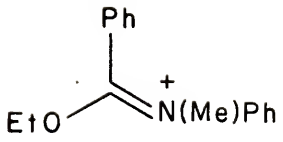
With the added purpose of better defining the scope of the iminium salt deprotonations described in Chapter I,

it was proposed that potential 2-azirine precursors of type 88 might be accessible via the deprotonation of those iminium salts (97) which were substituted with good leaving groups (X), as shown in Scheme XVII. Based

Scheme XVII

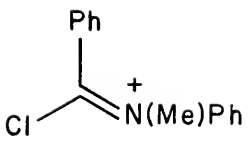


on the successful alkylations described in the preceding chapter, two likely candidates for 97 were compounds 98 and 99. The former compound, in addition, offered the possibility of producing an aziridine intermediate which was sufficiently stable to the reaction conditions to



$^{-}OSO_2CF_3$

98



$^{-}OSO_2F$

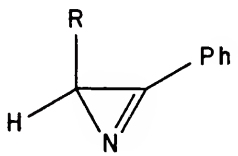
99

enable its isolation. The isolation of 2-alkoxyaziridines under strongly basic conditions has been reported, for example, by Sato.[47]

A second approach to the synthesis of 2-azirines from intact three-membered rings involves the isomerization of 1-azirines (89, Scheme XV). In most of the reported cases, the 1-azirines were used as precursors to aziridines of type 88. It is not unlikely that the failure of this approach has been due, at least in part, to the relatively high nucleophilicities of the potential leaving groups attached to 88. Accordingly, the cyclic iminium salts 91 (in which Y is a very poor nucleophile) were envisioned as suitable precursors to 90. The other synthetic approach to the 2-azirine system which will be described in this chapter, then, will involve the attempted generation and deprotonation of alkylated 1-azirines.

Although 1-azirines have been protonated,[48] attempts

to alkylate them have generally met with failure (owing to the low nucleophilicity of the 1-azirine nitrogen atom[35,37]). For example, compounds 100b and 100d were found to be unreactive toward methyl iodine and benzyl chloride in refluxing acetone.[37] It was hoped, however,



100

a, R = H

b, R = Ph

c, R = CO_2Et

d, R = Me

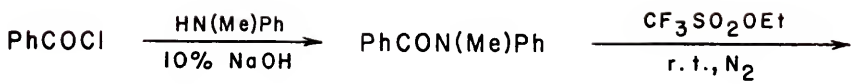
that the very potent alkylating agent, methyl triflate (acting as RY in Scheme XV), would ensure alkylation of the 1-azirines. The three compounds that were used to test this approach were the known azirines 100a, b, and c. These particular ones were chosen largely on the basis of their synthetic accessibility and relative thermal stability.

The Aziridine Approach

Results

The required α-alkoxyiminium salt 98 was prepared in 91% yield by the O-alkylation of N-methylbenzanilide (101) with ethyl triflate, as shown in Scheme XVIII. The product is a white solid which can be recrystallized from

Scheme XVIII



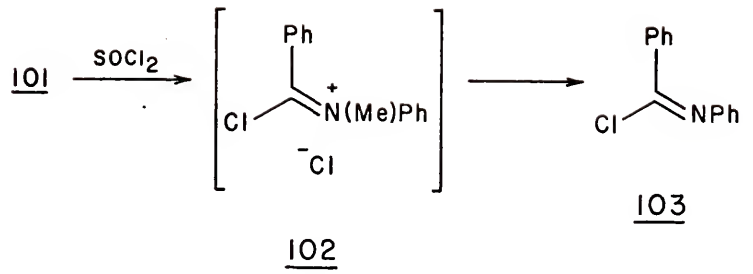
101

$^{-}OSO_2CF_3$ $^{-}OSO_2CF_3$

98a 98b

absolute ethanol. Its NMR SPECTRUM 20 clearly indicates the presence of the two configurational isomers, 98a and 98b.

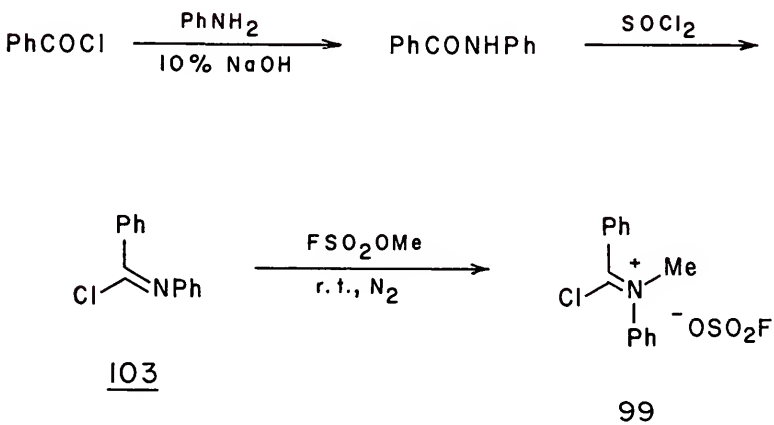
Synthesis of a model α-chloroiminium salt was attempted first by treating amide 101 with thionyl chloride, as shown in equation 18. The major reaction product, however, was the imidoyl chloride 103, formally the result of a von Braun degradation[49] of the desired iminium salt 102. It was subsequently found that 103 could be alkylated in moderate (46%) yield with methyl fluorosulfonate, as shown



(18)

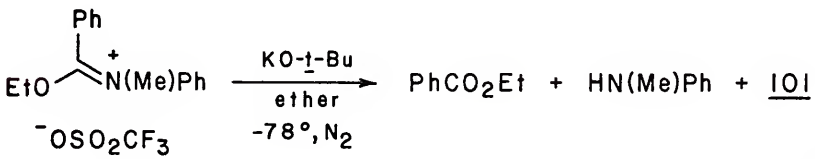
in Scheme XIX. Data taken from NMR SPECTRUM 21 of the product suggest a single isomer, presumably structure 99.

Scheme XIX



Results of the deprotonation experiments were disappointing. Treatment of the α-ethoxyiminium salt 98 with potassium tert-butoxide in ether at -78° afforded

only ethyl benzoate, N-methyl aniline, and N-methylbenzanilide (101) in a molar ratio of 1:1:0.8 (equation 19). The reaction of 98 with sodium bis(trimethylsilyl)amide in benzene at 0° produced a mixture in which nothing could be identified.

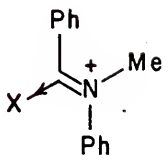


98 (19)

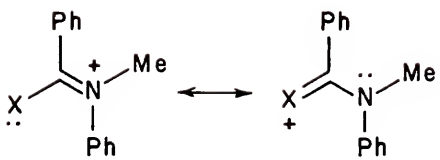
Similarly, treatment of salt 99 with $NaN(SiMe_3)_2$ in benzene produced a dark oil, whose nmr spectrum indicated a complex mixture. Repeated attempts to separate components of the mixture by column chromatography were unsuccessful.

Discussion

In view of the paucity of information about the products that were formed in these deprotonation reactions, one can not rigorously justify the apparent failure of this approach. It can not even be assumed, for example, that deprotonation took place at all! Indeed, although one would expect the inductive effect (104) of the heterosubstituent of compound 97 to enhance the acidity of the N-methyl protons, the resonance contribution (105) should render these protons less acidic, in addition to making the α-carbon atom more electrophilic. At least in the case



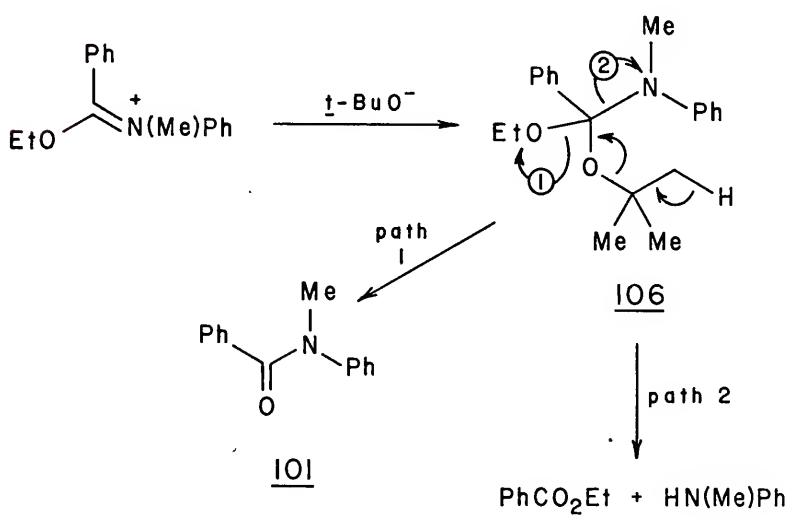
104



105

of the reaction between the α-ethoxyiminium salt 98 and potassium tert-butoxide, it is possible to explain the results obtained by postulating first nucleophilic attack by the base, followed by collapse of the resulting ketal

Scheme XX



106* to produce the observed products, as shown in Scheme XX. Of course, one can not exclude the possibility that these products resulted, at least in part, from simple hydrolysis by traces of moisture in the reaction mixture. Also, there is some precedent for the Chapman rearrangement of compounds such as 98 to afford amides corresponding to 101.[51]

The unpromising results of this aziridine approach to the synthesis of the 2-azirine system prompted the investigation of the second approach, which was outlined above.

The 1-Azirine Approach

Results

Two of the 1-azirines used in this study, compounds 100a[52a] and 100b,[52b] were prepared according to published procedures[52] by pyrolysis of the corresponding vinyl azides (107), as shown in Scheme XXI. The 3-carbethoxy derivative 100c was prepared by the thermal rearrangement of isoxazole 108, according to the procedure of Nishiwaki.[53]

All alkylations were performed in a nitrogen-purged drybox. The addition of two drops of methyl triflate to

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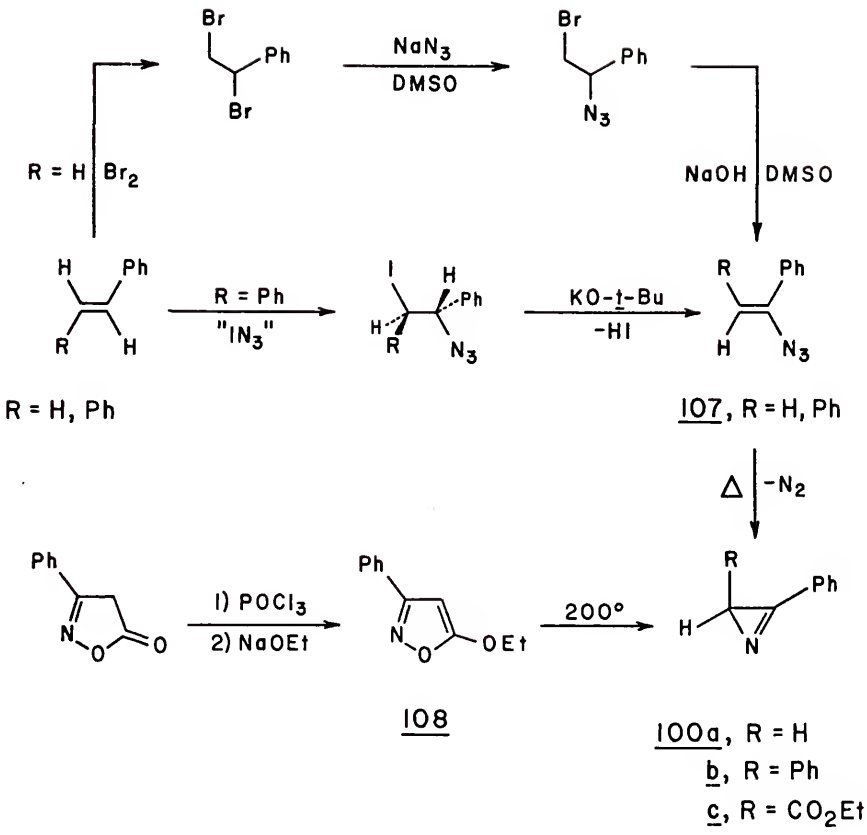
*There is ample published precedent for the formation of intermediates of type 106 from α-chloroiminium salts (e.g., see reference 50); also, recall the major product (48) of the reaction of aldiminium salt 14a with potassium tert-butoxide (Scheme V, p 23).

Scheme XXI



neat 2-phenyl-1-azirine (100a) resulted in an immediate explosion! The reaction mixture smoked and blackened before collapsing to an intractable tar. Less stringent conditions were tried: a 0.5 M solution of 100a in carbon tetrachloride was frozen at -78°, and an equimolar solution of methyl triflate in dichloromethane (a liquid

at -78°) was layered onto the first solution. Upon thawing and mixing, however, the system darkened. It gradually deposited a black oil, which was not investigated further.

The two-phase technique was next tried with 2,3-diphenyl-1-azirine, compound 100b. Initially, the frozen solution of 100b in carbon tetrachloride showed no visible evidence of reacting with the methyl triflate solution at low temperature. It was only after allowing the mixture to warm to ambient temperature, and stirring for several hours, that bright yellow crystals precipitated from the solution. Elemental and spectral characterization of the isolated solid suggested structure 109 in Scheme XXII (two crops afforded 46% of the theoretical yield). For example, NMR SPECTRUM 22 of the product showed a deshielded, three-proton singlet at δ3.31, and a one-proton singlet at δ6.34. These were assigned to the methyl and vinyl protons of 109, respectively.* As shown in Scheme XXII, this structural assignment was substantiated by treating compound 109 with dilute, aqueous sodium hydroxide. The free base (110, NMR SPECTRUM 23) was produced in quantitative yield. Reprotonation of 110 with trifluoromethanesulfonic acid returned compound 109. In addition, 109 was converted to the alkylated pyrazine 111 (NMR SPECTRUM 24) by refluxing it with

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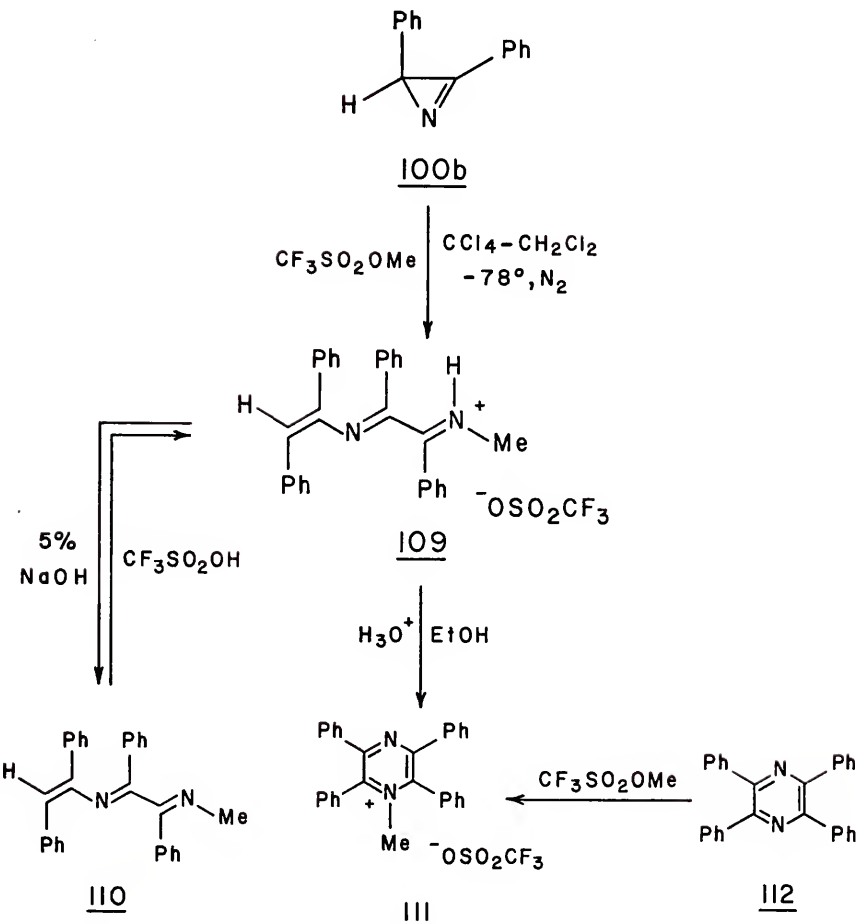
*Cf. the following data on the corresponding protons of the free base, 110 (vide infra): δ2.98 (singlet, 3H, CH_3) and 5.78 (singlet, 1H, vinyl).

Scheme XXII



dilute, aqueous hydrochloric acid in ethanol. Product 111, in turn, was found to be identical (by nmr spectral comparison and mixture melting point determination) to that obtained by the alkylation of an authentic sample of tetraphenylpyrazine (112)[54] with methyl triflate.

The alkylation of azirine 100b was repeated in a sealed nmr sample tube, using a CCl_4-SO_2 solvent system. Periodic nmr spectral assay of the homogeneous system after it had warmed to room temperature (defined as time t_o) revealed that most of the 1-azirine was consumed within one hour after t_o. The diazatriene 109 was formed between 2 and 3.5 hours after t_o. It began to decompose 24 hours later, however, to what was apparently the alkylated pyrazine, 111.*

The 3-carbethoxy azirine 100c was also subjected to the two-phase alkylation conditions. Spectroscopic assay of the reaction mixture one day after the addition of the methyl triflate indicated that little reaction had taken place during this period. The azirine was totally consumed within one week, however, but the decomposition products were not identified.

Discussion

The formation of 109 from 100b can be explained by several related mechanisms, one of which is suggested in Scheme XXIII. Alkylation of the 1-azirine would produce the cyclic iminium salt 114. In preference to deprotonation, thereby generating the 2-azirine 115, intermediate 114 could open to form the more stable aza-allylic cation (113). There are several literature precedents for the

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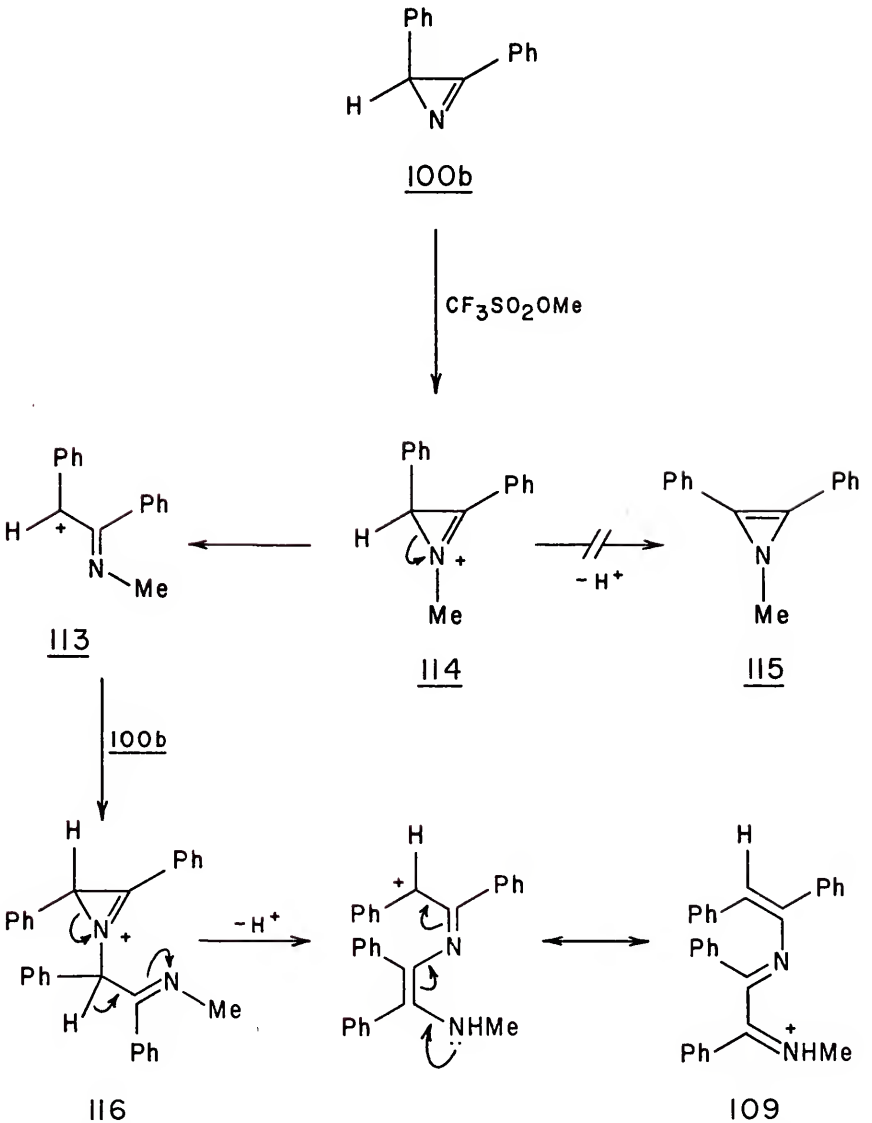
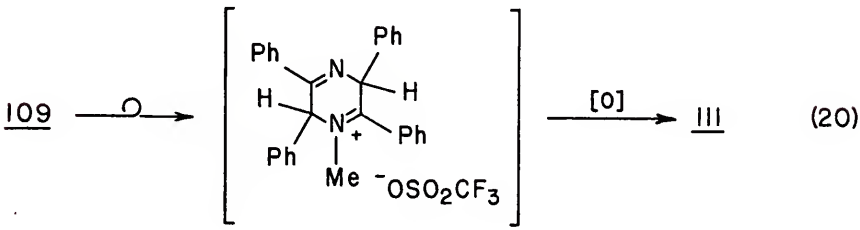
*The behavior of two additional, unidentified resonances is described in Chapter III, p 121.

Scheme XXIII



cleavage of aziridinyl cations such as 114.[26b,48,55] Alkylation of 113 by a molecule of the intact azirine would afford 116 which, by another ring opening and tautomerization, would produce the observed product, 109. Formation of the pyrazinium salt 111 from 109 probably takes place via intermediate 117, followed by spontaneous air oxidation, as shown in equation 20.



117 (20)

Although azirine 100c was chosen for study partly with the expectation that its ester substituent would discourage formation of the cation corresponding to 113, there is no evidence that this effect was responsible for the sluggish reaction of 100c with methyl triflate. Rather, it is likely that the electron-withdrawing effect of the ester group deactivated the azirine nitrogen atom to alkylation. Nishiwaki et al. have made similar observations.[53b]

CHAPTER III

EXPERIMENTAL

Melting points were determined with a Thomas-Hoover Unimelt capillary melting point apparatus and are uncorrected. All temperatures are given in °C. Infrared spectra were recorded with a Perkin-Elmer Model 137 spectrometer. Nuclear magnetic resonance (nmr) spectra were recorded on a 60 MHz Varian Associates A-60A high-resolution spectrometer at a sweep width of 500 Hz. Chemical shifts (δ) are reported in parts per million downfield from internal tetramethylsilane standard. Low-resolution mass spectra were measured on either an Hitachi Perkin-Elmer RMU-6E spectrometer or an AEI-MS-30 double-beam instrument. Microanalyses were performed by Atlantic Microlab, Inc., Atlanta, Georgia.

Thin-layer chromatography (tlc) was accomplished with Eastman Silica Gel Chromagram Paper with fluorescent indicator. Results were visualized by exposure to ultraviolet light and iodine vapor. Solvent evaporations were performed with a Buchler rotary evaporator equipped with a water aspirator. Except as noted, the syntheses, isolations and reactions of moisture-sensitive compounds were effected in a Labconco (Kansas City, Missouri) fiberglass drybox purged

with dry nitrogen and equipped with an aspirator for suction filtration. All glassware used in the drybox was dried in an oven (ca. 100°) for at least eight hours.

All reagents were used as purchased and were Reagent Grade, unless otherwise indicated. Anhydrous solvents were generally prepared by drying over Linde molecular sieves, size 3A or 4A.

General Procedure for the Preparation of the Ketimines (9). The ketimines (9) were prepared by slight modification of the method of Moretti and Torre.[10] A three-necked 2000-ml round-bottomed flask was equipped with a 250-ml pressure-equalized addition funnel, gas inlet, and reflux condenser with a Drierite drying tube. The entire apparatus was flamed with a Bunsen burner while being purged with dry nitrogen. The flask was then cooled with an ice bath, and a thermometer and magnetic stirrer were inserted. To the flask was added a solution of benzophenone (Eastman, 18.22 g, 0.100 mol) and a tenfold excess of the appropriate amine in dichloromethane (500 ml). Next, a solution of titanium (IV) chloride (Ventron, 12.4 g, 7.2 ml, 0.065 mol) in dichloromethane (200 ml) was added dropwise over a period of ca. 60 minutes, while maintaining the temperature below 5°. The mixture was stirred at room temperature for 3-6 days, while monitoring the progress of the reaction by infrared spectral assay ($\nu_{C=N}^{CCl_4}$ ca. 1620 cm^{-1}) of aliquots. When the reaction was complete, the mixture was filtered through

glass wool. The filtrate was washed with saturated sodium chloride, treated with anhydrous magnesium sulfate and activated charcoal, and concentrated *in vacuo* to afford the crude ketimine (9). If necessary, the products were purified by distillation or recrystallization.

N-(Benzhydrylidene)*tert*-butylamine (9a). *N*-(Benzhydrylidene)-*tert*-butylamine (9a)[10] was prepared according to the general procedure from *tert*-butylamine (MC/B Manufacturing Chemists, 69.6 g, 100 ml, 0.95 mol). The mixture was stirred for six days. Work-up afforded the crude 9a (22.0 g, 93%): mp 33.5-35.5° (lit.[10] 35-36°); nmr (CCl_4) δ1.13 (singlet, 9H, *tert*-butyl), 6.9-7.6 (multiplet, 10H, aromatic).

N-(Benzhydrylidene)methylamine (9b). This compound was prepared in the usual manner from methylamine hydrochloride (MC/B, 67.5 g, 1.00 mol) and triethylamine (101 g, 139 ml, 1.00 mol). The mixture was worked-up after one week to afford the crude product (18.7 g, 96%). Bulb-to-bulb distillation (0.10 mm) with a rotary evaporator and a Bunsen burner produced the pure *N*-(benzhydrylidene)methylamine (9b,[10] 16.7 g, 85%) as a clear, colorless oil: nmr (CCl_4) δ3.15 (singlet, 3H, CH_3), 6.9-7.7 (multiplet, 10H, aromatic).

N-(Benzhydrylidene)allylamine (9c). This compound was synthesized from allylamine (Eastman, 57.1 g, 75 ml, 1.00 mol) according to the general procedure. Work-up after stirring the mixture for 18 hours afforded the crude product (20.5 g, 93%) as a viscous, orange oil. The material was

distilled (0.05 mm) with a rotary evaporator and Bunsen burner to afford the pure N-(benzhydrylidene)allylamine (9c)[56] as a clear, pale yellow oil: nmr (CCl_4) δ3.8-4.1 (multiplet, 2H, allyl), 4.8-5.3 (multiplet, 2H, $=CH_2$), 5.7-6.3 (multiplet, 1H, $CH_2=CH$), 6.9-7.8 (multiplet, 10H, aromatic).

N-(Benzhydrylidene)benzhydrylamine (9d). The general procedure for the preparation of the ketimines was followed on a 0.050 mole scale, using dry benzene (instead of dichloromethane) and benzhydrylamine (Aldrich, 96%, 91.6 g, 0.480 mol). The mixture was worked-up after three days, and the excess amine was removed by washing a solution of the crude product in ether (300 ml) with 2% aqueous hydrochloric acid (2x200 ml). The resulting interfacial solid was combined with the ethereal extract, and the solvent was removed *in vacuo*. The dried, pure white product (10.9 g, 63%) melted at 150.5-152° (lit.[57] 154°) and showed the following nmr spectrum ($CDCl_3$): δ5.56 (singlet, 1H, benzhydryl), 6.9-7.9 (multiplet, 20H, aromatic).

N-(Benzhydrylidene)aniline (9e). N-(Benzhydrylidene)aniline (9e)[58] was prepared from aniline (Mallinckrodt, 93.1 g, 91 ml, 1.00 mol) in the usual manner. The mixture was worked-up after five days, and the crude product was recrystallized from absolute ethanol to produce pure 9e (20.7 g, 81%): mp 112-113° (lit.[58] 117°); nmr (CCl_4) δ6.4-7.8 (multiplet, aromatic).

N-(Fluorenylidene)methylamine (18a). The general procedure for the preparation of the ketimines was modified for the preparation of compound 18a. A solution of methylamine hydrochloride (MC/B, 33.8 g, 0.500 mol) and triethylamine (freshly distilled, 50.6 g, 70.0 ml, 0.500 mol) in dichloromethane (250 ml) was added to a solution of fluoren-9-one (MC/B, 9.01 g, 0.050 mol) in dichloromethane (100 ml). After the addition of molecular sieves (3A, ca. 5 g), the stirring mixture was cooled to 0-5°, and a solution of titanium (IV) chloride (6.2 g, 3.6 ml, 0.033 mol) in dichloromethane (100 ml) was added over a period of 30 minutes. The usual work-up after five days afforded crude N-(fluorenylidene)methylamine (18a, 8.87 g, 92%) as a clear, dark amber oil: nmr (CCl_4) δ3.68 (singlet, 3H, CH_3), 6.6-7.9 (multiplet, 8H, aromatic).

N-(Fluorenylidene)tert-butylamine (18b). N-(Fluorenylidene)-tert-butylamine (18b) was prepared as follows: a solution of titanium (IV) chloride (6.2 g, 3.6 ml, 0.033 mol) in dichloromethane (100 ml) was added over a period of 30 minutes to a stirring solution of fluoren-9-one (9.01 g, 0.050 mol), tert-butylamine (34.8 g, 50 ml, 0.48 mol), and dichloromethane (350 ml), at 0-5°. Conventional work-up after two days afforded crude 18b (10.9 g, 92%) as a yellow powder: mp 52-55°; nmr (CCl_4) δ1.58 (singlet, 9H, tert-butyl), 7.0-7.9 (multiplet, 8H, aromatic).

General Procedure for the Preparation of the Ketiminium

Salts (12 and 13). A 500-ml round-bottomed flask was equipped with a magnetic stirrer, placed in a drybox, and charged with the appropriate ketimine (9, 0.05-0.08 mol) and dry solvent. The flask was immersed in a Dry Ice-acetone bath and treated with approximately two equivalents of the appropriate alkylating agent. The cold bath was removed, and the system was stirred overnight at ambient temperature. The ketiminium salts thus prepared were collected by suction filtration in the drybox, washed with ether, dried, and weighed.

In these and all succeeding alkylations, the methyl fluorosulfonate (11a) was obtained from the Aldrich Chemical Company, Inc. ("Magic Methyl," 97%); methyl triflate (11b) was obtained from Willow Brook Laboratories, Inc. (Waukesha, Wisconsin). Both materials were used without further purification.

N-(Benzhydrylidene)methyl-tert-butylaminium Fluorosulfonate (12a). The general alkylation procedure was carried out with a mixture of N-(benzhydrylidene)tert-butylamine (9a, 11.87 g, 50.0 mmol), methyl fluorosulfonate (11a, 10.6 g, 7.5 ml, 93 mmole), and anhydrous ether (75 ml). The crude N-(benzhydrylidene)methyl-tert-butylaminium fluorosulfonate (12a, 16.95 g, 97%) melted with decomposition at 125°. Three recrystallizations from absolute ethanol produced the analytical sample of 12a: mp 128-128.5° dec; ir (Nujol) ν1590, 1290, 1180, 1080 cm^{-1}; NMR SPECTRUM 1 (SO_2) δ1.58 (singlet, 9H, tert-butyl), 3.78 (singlet, 3H, NCH_3), 7.2-7.8

(multiplet, 10H, aromatic); mass spectrum (15eV) m/e 41, 56 (base), 118, 194, 195; (70eV) m/e 77, 118 (base), 194, 195 (P^+ 351 unobsd).

Anal. Calcd for $C_{18}H_{22}FNO_3S$: C, 61.51; H, 6.31; N, 3.99. Found: C, 61.40; H, 6.39; N, 4.02.

N-(Benzhydrylidene)methyl-tert-butylaminium Triflate (13a). This compound was prepared by a modification of the general alkylation procedure. Into a 25-ml round-bottomed flask equipped with a magnetic stirrer was placed N-(benzhydrylidene)tert-butylamine (9a, 2.85 g, 12 mmol) and dry chloroform (10 ml). The solution was stirred in an atmosphere of nitrogen, cooled to 0°, and treated with methyl triflate (1.97 g, 2.00 ml, 12 mmol). The opaque mixture was stirred at room temperature for 4.5 hours, and then concentrated in vacuo. Trituration of the residue with anhydrous ether produced a solid, which was collected by filtration, washed with ether, and dried. The crude N-(benzhydrylidene)methyl-tert-butylaminium triflate (13a) was isolated in quantitative yield. It melted with decomposition at 113°. Two recrystallizations from ethanol-ether afforded the analytical sample: mp 114-115.5° dec; nmr (DMSO-d_6) δ1.48 (singlet, 9H, tert-butyl), 3.68 (singlet, 3H, NCH_3), 7.58 (ca. singlet, ca. 10H, aromatic).

Anal. Calcd for $C_{19}H_{22}F_3NO_3S$: C, 56.84; H, 5.52; N, 3.49. Found: C, 56.75; H, 5.60; N, 3.48.

N-(Benzhydrylidene)dimethylaminium Fluorosulfonate (12b).

The general alkylation procedure was carried out with a mixture of N-(benzhydrylidene)methylamine (9b, 15.6 g, 80 mmol), methyl fluorosulfonate (11a, 17.0 g, 12.0 ml, 150 mmol), and ether (200 ml). Additional ether (150 ml) was added after the mixture had warmed to ambient temperature, to facilitate stirring. The usual work-up afforded N-(benzhydrylidene)dimethylaminium fluorosulfonate (12b, 24.6 g, 100%) as a white powder, which melted at 131-142°. NMR SPECTRUM 2 (SO_2) showed δ3.86 (singlet, 6H, CH_3), 7.6-7.9 (multiplet, 10H, aromatic).

N-(Benzhydrylidene)methylallylaminium Fluorosulfonate (12c). Crude N-(benzhydrylidene)methylallylaminium fluorosulfonate (12c, 16.47 g, 98%) was prepared from N-(benzhydrylidene)allylamine (9c, 11.07 g, 50.0 mmol), methyl fluorosulfonate (11a, 10.6 g, 7.5 ml, 93 mmol), and ether (100 ml), according to the general alkylation procedure. Salt 12c melted at 83.5-91° and showed NMR SPECTRUM 3 (SO_2): δ3.80 (singlet, 3H, CH_3), 4.71 (broad doublet, J=ca. 5.8 Hz, 2H, allyl), 5.4-6.5 (multiplet, 3H, vinyl), 7.4-7.7 (multiplet, 10H, aromatic).

N-(Benzhydrylidene)methylbenzhydrylaminium Fluorosulfonate (12d). The general alkylation procedure was modified for the preparation of salt 12d. Into an oven-dried 50-ml round-bottomed flask was placed N-(benzhydrylidene)benzhydrylamine (9d, 5.21 g, 15 mmol) and dry chloroform (35 ml). The solution was cooled with an ice bath, purged with dry

nitrogen, and stirred magnetically. The ice bath was removed after the rapid addition of methyl fluorosulfonate (11a, 4.95 g, 3.5 ml, 44 mmol), and the colorless solution was stirred at room temperature for one hour. The chloroform and excess alkylating agent were removed *in vacuo* to afford a viscous, pale yellow oil (9.83 g). Part of the oil crystallized upon trituration with ethanol and ether at -78°. The solid was collected by filtration and washed with ether. The crude *N*-(benzhydrylidene)methylbenzhydrylaminium fluorosulfonate (12d, 4.71 g, 68%) melted over a broad range (*ca.* 109-140°). Three recrystallizations from ethanol-ether produced 12d as a white powder, which melted at (162) 173-193° and showed NMR SPECTRUM 4 (DMSO-d_6): δ3.59 (singlet, 3H, CH_3), 6.87 (singlet, 1H, benzhydryl), 7.2-7.8 (multiplet, *ca.* 20H, aromatic).

N-(Benzhydrylidene)methylanilinium Fluorosulfonate (12e). The general alkylation procedure was applied to the synthesis of salt 12e, starting with *N*-(benzhydrylidene)aniline (9e, 12.87 g, 50.0 mmol), methyl fluorosulfonate (11a, 10.6 g, 7.5 ml, 93 mmol), and ether (125 ml). Ketimine 9e was found to be relatively insoluble in ether at -78°, but the alkylation proceeded in the usual fashion. The crude *N*-(benzhydrylidene)methylanilinium fluorosulfonate (12e, 17.79 g, 96%) was obtained as a pale yellow powder: mp 215.5-220°; NMR SPECTRUM 5 (SO_2) δ4.22 (singlet, 3H, CH_3), 7.33 (*ca.* singlet, 5H, aromatic), 7.51 (*ca.* singlet, 5H, aromatic), 7.73 (singlet, 5H, aromatic).

N-(Fluorenylidene)dimethylaminium Fluorosulfonate (19a). The general alkylation procedure was followed on a smaller scale for the synthesis of salt 19a. Addition of the methyl fluorosulfonate (11a, 2.12 g, 1.5 ml, 19 mmol) to the solution of N-(fluorenylidene)methylamine (18a, 1.93 g, 10 mmol) in dry chloroform (15 ml) produced an immediate, voluminous, orange precipitate. Magnetic stirring was facilitated by the addition of anhydrous ether (25 ml). The mixture was stirred for 30 minutes, and the crude N-(fluorenylidene)dimethylaminium fluorosulfonate (19a) was collected by filtration, washed with ether, and pulverized with a morter and pestle. The resulting pale orange powder (2.83 g, 92%) melted at 220-233° dec. Compound 19a was found to be insoluble in acetone (cf. salts 12 and 13). Its nmr spectrum (SO_2) showed δ4.17 (singlet, ca. 6H, CH_3), 7.2-8.0 (multiplet, ca. 8H, aromatic).

Pyrolysis of N-(Benzhydrylidene)methyl-tert-butylaminium Triflate (13a). N-(Benzhydrylidene)methyliminium Triflate (17). N-(Benzhydrylidene)methyl-tert-butylaminium triflate (13a, 2.01 g, 5.0 mmol) was placed in a 2x20-cm Pyrex pyrolysis tube equipped for quantitating gas evolution. The tube was evacuated, filled with dry nitrogen, and heated with an oil bath at about 130°, until the volume of collected gas (98 ml, ca. 90% of the theoretical amount of isobutene) remained constant. Upon cooling, the melt solidified. The pyrolysis tube was cracked open and the crude N-(benzhydrylidene)methyliminium triflate (17) was

recovered in quantitative yield: mp 108-110°; nmr (DMSO-d_6) δ3.47 (singlet, ca. 3H, CH_3), 7.70 (ca. singlet, ca. 10H, aromatic).

Attempted Alkylation of N-(Fluorenylidene)tert-butylamine (18b) with Methyl Fluorosulfonate (11a). N-(Fluorenylidene)-tert-butyliminium Fluorosulfonate (19b). Into an oven-dried 100-ml round-bottomed flask was placed N-(fluorenylidene)-tert-butylamine (18b, 4.71 g, 0.020 mol) and dry chloroform (30 ml). Methyl fluorosulfonate (11a, 4.24 g, 3.0 ml, 0.037 mol) was then added to the stirring solution at 0° in an atmosphere of dry nitrogen. The dark mixture was allowed to warm to room temperature, stirred for 15 minutes, and treated with anhydrous ether (50 ml). The resulting dark red precipitate was collected by filtration. Two additional crops were isolated from the refrigerated filtrates over a period of three days. The total recovery of N-(fluorenylidene)-tert-butyliminium fluorosulfonate (19b, 4.25 g) was 63%. The third crop (1.34 g), for example, decomposed sharply at 183° and showed the following nmr spectrum (SO_2): δ1.91 (singlet, 9H, tert-butyl), 7.2-8.2 (multiplet, 8H, aromatic), 9.2-11.3 (broad singlet, ca. 1H, NH).

Attempted Alkylation of N-(Benzhydrylidene)tert-butylamine (9a) with Ethyl Triflate. N-(Benzhydrylidene)tert-butyliminium Triflate (20). A solution of N-(benzhydrylidene)tert butylamine (9a, 4.75 g, 0.020 mol) in dry chloroform (20 ml) was stirred magnetically in a 50-ml round-bottomed flask.

The system was purged with dry nitrogen and cooled with an ice bath, after which ethyl triflate (Willow Brook Laboratories, Inc., 98%, 3.92 g, 0.022 mol) was added. The resulting pale yellow solution was allowed to warm to room temperature, and was stirred in an atmosphere of dry nitrogen for 48 hours. The white precipitate that formed during this time was collected by filtration, washed with ether, and dried. N-(Benzhydrylidene)tert-butyliminium triflate (20, 1.38 g, 18%) was found to melt with decomposition at 180°. Two recrystallizations from absolute ethanol afforded the analytical sample of 20 as fluffy, white crystals: mp 178-179.5° dec; NMR SPECTRUM 6 (DMSO-d_6) δ1.40 (singlet, 9H, tert-butyl), 7.4-7.9 (multiplet, 10H, aromatic); mass spectrum (70eV) m/e 180, 222 (base), 237 (P^+ 387 unobsd).

Anal. Calcd for $C_{18}H_{20}F_3NO_3S$: C, 55.80; H, 5.20; N, 3.62. Found: C, 55.70; H, 5.28; N, 3.58.

Pyrolysis of N-(Benzhydrylidene)tert-butyliminium Triflate (20). N-(Benzhydrylidene)iminium Triflate (21). N-(Benzhydrylidene)tert-butyliminium triflate (20, 0.50 g, 1.3 mmol) was placed in an oven-dried 2x15-cm Pyrex pyrolysis tube equipped with a gas outlet which was connected to a drying tube. The pyrolysis tube was immersed in an oil bath to a depth of 4 centimeters. The system was heated at 180-195°, until gas evolution had ceased (about 15 minutes). Upon cooling, the clear, colorless melt solidified

as long white needles. The crude N-(benzhydrylidene)-iminium triflate (21, 0.42 g, 98%) melted at 162-166°. The analytical sample was obtained after two recrystallizations from ethanol-ether: mp 167-169.5°; nmr (DMSO-d_6) δ7.5-8.1 (multiplet, ca. 10H, aromatic), 12.2 (broad singlet, ca. 2H, NH_2); mass spectrum (70eV) m/e 77, 105 (base), 182 (P^+ 331 unobsd).

Anal. Calcd for $C_{14}H_{12}F_3NO_3S$: C, 50.75; H, 3.65; N, 4.23. Found: C, 50.50; H, 3.75; N, 4.15.

Treatment of N-(Benzhydrylidene)tert-butyliminium Triflate (20) with Aqueous Base. N-(Benzhydrylidene)tert-butylamine (9a). Into a 1.5x15-cm test tube was placed N-(benzhydrylidene)tert-butyliminium triflate (20, 1.00 g, 2.58 mmol). A solution of 10% aqueous sodium hydroxide (10 ml) was added, and the resulting white gum was stirred magnetically for five minutes. The mixture was extracted with dichloromethane, and the separated organic layer was washed with water, dried with anhydrous magnesium sulfate, and concentrated in vacuo. The nmr spectrum of the residue (0.56 g) was identical to that of authentic N-(benzhydrylidene)tert-butylamine, 9a (vide supra). The yield of the free base 9a was 92%.

Treatment of N-(Benzhydrylidene)methyl-tert-butylaminium Fluorosulfonate (12a) with n-Butyllithium (23). N-(Benzhydrylidene)methyl-tert-butylaminium fluorosulfonate (12a, 0.53 g, 1.5 mmol) was placed in a 25-ml round-bottomed

flask, in a drybox. To it was added with magnetic stirring a solution of n-butyllithium (23) in hexane (MC/B, 15.1%, 1.00 ml, 1.7 mmol). An immediate, deep red color developed (and persisted) during the addition of anhydrous ether (10 ml). The mixture was stirred for one hour, removed from the drybox, and filtered. The red filtrate turned dark yellow upon exposure to the air. Evaporation of the solvent *in vacuo* left a yellow oil (0.34 g) whose nmr spectrum indicated a mixture which contained little, if any, of the 1-*tert*-butyl-2,2-diphenylaziridine (22, *vide infra*).

Treatment of 12a with 1,8-Bis(dimethylamino)naphthalene (24). An oven-dried three-necked 25-ml round-bottomed flask was fitted with a gas inlet, serum cap, drying tube, and magnetic stirrer. To the flask was added N-(benzhydrylidene)methyl-*tert*-butylaminium fluorosulfonate (12a, 0.53 g, 1.5 mmol) and base 24[20] (Aldrich, "Proton Sponge," 0.34 g, 1.6 mmol). The system was purged with dry nitrogen and cooled to -78°, and anhydrous ether (10 ml) was added *via* the serum cap with stirring. The cold bath was removed ten minutes after the addition, the serum cap was replaced by a reflux condenser, and the off-white slurry was refluxed overnight. The mixture was then filtered, and the ether-insoluble material was found by nmr spectroscopy to be the unreacted ketiminium salt, 12a (0.52 g, 98% recovered, mp 125-125.5° dec).

Treatment of 12a with Lithium 2,2,6,6-Tetramethylpiperidide (25). A 50-ml round-bottomed flask was placed in a drybox and charged with N-(benzhydrylidene)methyl-tert-butylaminium fluorosulfonate (12a, 1.05 g, 3.00 mmol), 2,2,6,6-tetramethylpiperidine[59] (0.44 g, 3.10 mmol), and anhydrous ether (20 ml). A solution of 1.9 M n-butyllithium in hexane (MC/B, 1.63 ml, 3.10 mmol) was then added with magnetic stirring. The deep red mixture was stirred overnight, during which time it changed to a light brown slurry. The slurry was removed from the drybox and concentrated in vacuo. Ether and water were added to the residue, and the separated ethereal layer was washed with saturated sodium chloride, dried with anhydrous magnesium sulfate, and evaporated to a viscous, amber oil (0.81 g). The nmr spectrum of the oil indicated the presence of 2,2,6,6-tetramethylpiperidine [δ1.05 (singlet, CH_3)] in addition to 1-tert-butyl-2,2-diphenylaziridine (22) and N-(benzhydrylidene)-tert-butylamine (9a). Estimation of the relative proportions of the latter two compounds (ca. 0.7:1) was made by comparison of the peak heights of their respective tert-butyl resonances.

Treatment of 12a with Lithium 2,6-Di-tert-butylphenoxide (26). A 25-ml round-bottomed flask equipped with a magnetic stirrer was placed in a drybox, and into it was placed a solution of 2,6-di-tert-butylphenol (Aldrich, min 99%, 0.41 g, 2.0 mmol) in anhydrous ether (10 ml). To the stirring solution was added a solution of 1.9 M

n-butyllithium in hexane (1.00 ml, 1.9 mmol). The resulting white slurry of lithium 2,6-di-tert-butylphenoxide (26) was stirred at ambient temperature for 10 minutes; cooled with a Dry Ice-acetone bath, and stirred for 15 minutes at -78°. N-(Benzhydrylidene)-methyl-tert-butylaminium fluorosulfonate (12a, 0.56 g, 1.5 mmol) was then added rapidly. The mixture was stirred at -78° for 15 minutes, and allowed to warm to ambient temperature. After stirring for an additional 60 minutes, the insoluble material was collected by filtration, washed with ether, and found by nmr spectral analysis to be the unreacted iminium salt 12a (0.40 g, ca. 70% recovered, mp 118-118.5° dec). The combined filtrate and washes were evaporated in vacuo to produce an oil (0.68 g), which was shown by nmr spectroscopy to be a mixture of which half (on a molar basis) was 2,6-di-tert-butylphenol [δ1.40 (singlet, tert-butyl)]. The remainder of the mixture was largely 22 and 9a in a ratio of 1.3:1.

Treatment of 12a with Sodium Dimsylate (27). A solution of N-(benzhydrylidene)methyl-tert-butylaminium fluorosulfonate (12a, 5.27 g, 15.0 mmol) in dry dimethyl sulfoxide (50 ml) was stirred in a 200-ml round-bottomed flask in a drybox. A dispersion of sodium hydride in mineral oil (Ventron, 57%, 0.85 g, 20 mmol) was then washed with ether, and the washed sodium hydride was added as a solution in DMSO (50 ml) to the iminium salt solution. The tan mixture was stirred at ambient temperature for four hours, during

which time it darkened appreciably. The system was removed from the drybox, most of the solvent was removed at reduced pressure, and the residue was treated with ether. The ethereal solution was washed with water and saturated sodium chloride, treated with activated charcoal and anhydrous magnesium sulfate, and filtered through Celite. Concentration of the filtrate *in vacuo* afforded a yellow syrup (3.62 g). The syrup was triturated with cold ether, and the resulting precipitate (0.31 g*) was removed by filtration. The filtrate was evaporated *in vacuo* to produce a clear, amber oil, whose nmr spectrum indicated the presence of aziridine 22, imine 9a, and benzophenone in the ratio of 1.8:1:0.2.

Treatment of 12a with Potassium *tert*-Butoxide (28) in Hexamethylphosphoramide. A 25-ml round-bottomed flask equipped with a magnetic stirrer, gas inlet, and drying tube was placed in a drybox. The flask was charged with *N*-(benzhydrylidene)methyl-*tert*-butylaminium fluorosulfonate (12a, 0.56 g, 1.5 mmol) and potassium *tert*-butoxide[61] (28, PCR, Inc., 0.19 g, 1.7 mmol). The system was closed to the atmosphere, removed from the drybox, and immersed in an ice bath. Dry hexamethylphosphoramide (Eastman, 10 ml) was added to the stirring solids in an atmosphere of

*This material was shown to be $Ph_2C(OH)CH_2S(O)Me$, formally derived from the condensation of sodium dimsylate and benzophenone: mp 151-152° (lit.[60] 148-148.5°). Its nmr spectrum was identical to that of the authentic material, prepared according to reference 60.

dry nitrogen. The resulting dark red solution was stirred for two minutes, allowed to warm to room temperature, and stirred for an additional 4.5 hours, during which time the solution turned amber. The solvent was removed at reduced pressure (0.20 mm), and the residue was treated with carbon tetrachloride. The CCl_4 solution was washed with water and saturated sodium chloride, dried with anhydrous magnesium sulfate, and concentrated *in vacuo* to furnish an oil (0.36 g) whose nmr spectrum showed a product distribution of 22:9a:Ph_2CO::0.4:1:0.8.

Treatment of 12a with Potassium tert-Butoxide (28) in Ether. A 25-ml round-bottomed flask was placed in a drybox, and charged with N-(benzhydrylidene)methyl-tert-butylaminium fluorosulfonate (12a, 0.53 g, 1.5 mmol) and potassium tert-butoxide (28, freshly sublimed, 0.18 g, 1.6 mmol). The mixture was cooled to -78°, and to it was added (with magnetic stirring) anhydrous ether (10 ml). The immediate pink color which developed gradually changed to pale yellow after the mixture had warmed to ambient temperature. The system was removed from the drybox after having stirred at 25° for one hour. It was filtered, and the filtrate was concentrated *in vacuo* to afford a viscous, clear, yellow oil (0.33 g) whose NMR SPECTRUM 11 showed a product ratio of 22:9a:Ph_2CO::13.4:1.0:2.6.

Preparation and Titration of a Solution of Potassium tert-Heptoxide (29) in Xylene. Potassium tert-heptoxide (29)

was prepared as a solution in p-xylene, by slight modification of one of the methods (Method B) of Acharya and Brown.[62] A solution of 3-ethyl-3-pentanol (Aldrich, 97%, 13.94 g, 0.116 mol) and potassium (0.39 g, 0.100 mol) in p-xylene (45 ml) was prepared in a drybox, in a 100-ml round-bottomed flask. The flask was stoppered, removed from the drybox, fitted with a reflux condenser and drying tube, and refluxed for nine hours. The resulting deep red mixture was cooled and filtered in the drybox to produce a clear, yellow* filtrate.

The filtrate was titrated three times, in exactly the same manner that the sodium bis(trimethylsilyl)amide solution was assayed (vide infra). It was found to be 0.14 M in potassium tert-heptoxide.

Treatment of 12a with Potassium tert-Heptoxide (29). N-(Benzhydrylidene)methyl-tert-butylaminium fluorosulfonate (12a, 0.53 g, 1.5 mmol) was stirred magnetically in a 25-ml round-bottomed flask in a drybox. To it was added the 0.14 M solution of potassium tert-heptoxide (29) in xylene (12 ml, 1.7 mmol). The resulting amber slurry was stirred for one hour and then filtered. Upon concentrating in vacuo, the filtrate afforded a clear, mobile, yellow oil (0.44 g) whose nmr spectrum showed 22:9a:Ph_2CO:Et_3COH:: 13.3:1.0:3.7:15.3.

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*Note that this color is at variance with the description in reference 62, which refers to the solution of 29 as a clear, red liquid.

Sodium Bis(trimethylsilyl)amide (30). Sodium bis(trimethylsilyl)amide (30) was prepared by slight modification of the method of Krüger and Niederprüm.[14] A 500-ml round-bottomed flask was placed in a drybox and charged with sodium amide (MC/B, Practical Grade, 19.51 g, 0.500 mol), hexamethyldisilazane (PCR, Inc., 80.7 g, 104 ml, 0.500 mol), molecular sieves (4A, ca. 10 g), and dry benzene (250 ml). The flask was stoppered and removed from the drybox. The black mixture was refluxed for four days, returned to the drybox, and filtered (hot) through Celite. The clear, colorless filtrate was evaporated to dryness in vacuo, first with a trapped water aspirator and then with a vacuum pump (ca. 0.03 mm). Precautions were taken to exclude moisture from the pure white powder. The sodium bis(trimethylsilyl)amide (30) was both weighed (81.02 g, 88%) and stored in the drybox.

Preparation and Titration of a Solution of Sodium Bis(trimethylsilyl)amide (30) in Benzene. A mixture of sodium bis(trimethylsilyl)amide (30, 22.01 g, 0.120 mol) and molecular sieves (4A, ca. 5 g) was stirred in dry benzene (300 ml) in a drybox until all of the base had dissolved. The molecular sieves and any insoluble impurities were separated from the solution by filtration through Celite in the drybox. The filtrate was diluted with more benzene (100 ml) and the solution was stored in the drybox in an amber bottle.

The solution of 30 in benzene was assayed by carefully

measuring three aliquots into 10-ml volumetric flasks, removing the flasks from the drybox, and quantitatively transferring their contents to three 100-ml round-bottomed flasks. Benzene was used to facilitate the transfer. The diluted aliquots were decomposed with distilled water (ca. 10 ml), and the resulting mixture was concentrated to dryness at reduced pressure. The residual sodium hydroxide was treated with distilled water (ca. 10 ml) and methyl red indicator (0.1% w/v in ethanol, 2 drops). In a typical assay, neutralization of the three samples required 25.9, 26.2, and 26.1 ml of standard 0.1000 M hydrochloric acid, indicating that the concentration of sodium bis(trimethylsilyl)amide in the benzene solution was 0.26(1) molar.

Treatment of 12a with Sodium Bis(trimethylsilyl)amide (30) in Liquid Sulfur Dioxide. A 25-ml round-bottomed flask equipped with a magnetic stirrer was placed in a drybox and charged with N-(benzhydrylidene)methyl-tert-butylaminium fluorosulfonate (12a, 0.53 g, 1.5 mmol) and sodium bis(trimethylsilyl)amide (30, 0.31 g, 1.7 mmol). The flask was stoppered with a serum cap, removed from the drybox, and joined via a hypodermic needle to a flamed vacuum manifold equipped with a source of dry nitrogen and a reservoir of liquid sulfur dioxide (dried over phosphorus pentoxide). The flask was cooled to -78° and liquid sulfur dioxide (ca. 10 ml) was condensed into it. The resulting

orange slurry* was stirred for one hour at -78°, after which time the sulfur dioxide was allowed to evaporate at room temperature. The residual tan gum was treated with ether and water, and the separated ethereal layer was washed with saturated sodium chloride, dried over anhydrous magnesium sulfate, and evaporated *in vacuo*. The nmr spectrum of the resulting yellow oil (0.08 g) indicated that *N*-(benzhydrylidene)*tert*-butylamine (9a) and benzophenone were the principal components of the crude product mixture. The presence of 1-*tert*-butyl-2,2-diphenylaziridine (22) was not detected in this spectrum.

Treatment of 12a with Sodium Bis(trimethylsilyl)amide (30) in Various Solvents at 25°C. Purification of 1-tert-Butyl-2,2-diphenylaziridine (22). A mixture of *N*-(benzhydrylidene)-methyl-*tert*-butylaminium fluorosulfonate (12a, 0.53 g, 1.5 mmol) and sodium bis(trimethylsilyl)amide (30, 0.29 g, 1.6 mmol) was stirred magnetically in a 25-ml round-bottomed flask, in a drybox. The appropriate solvent (10 ml) was added, and the mixture was stirred at ambient temperature for one hour. It was then removed from the drybox and filtered. The filtrate was concentrated *in vacuo*, and the residue was weighed and then assayed by careful integration of its nmr spectrum. The relative distributions of 1-*tert*-

*It was demonstrated in an independent experiment, too, that $NaN(SiMe_3)_2$ is largely insoluble in liquid SO_2 at this concentration.

butyl-2,2-diphenylaziridine (22), N-(benzhydrylidene)-tert-butylamine (9a), and benzophenone that were produced by these deprotonations are compiled in Table V.

The crude product from the reaction of 12a with $NaN(SiMe_3)_2$ in hexane was dissolved in carbon tetrachloride (10 ml) and applied to a 2.5x16-cm column of Fisher Adsorption Alumina (80-200 mesh), which was packed in 20-40° petroleum ether. The column was eluted with 150 ml of

Table V. Material Balance and Product Distribution Obtained from the Reaction of $[Ph_2C{=}N(Me)t\text{-}Bu](OSO_2F)$ (12a) with $NaN(SiMe_3)_2$ (30) in Various Solvents at 25°C

Solvent	Wt of crude product (g)	Mol-% product ratios, relative to $Ph_2C{=}N\text{-}t\text{-}Bu$ (9a)		
		22	9a	$Ph_2C{=}O$
DMSO	0.76[a]	11.4	1.0	4.3
ether	0.26	15.7	1.0	2.0
benzene	0.36	17.5	1.0	1.5
hexane	0.32	21.5	1.0	1.3

[a]Contaminated with DMSO and other (minor) products.

carbon tetrachloride, at which point a 25-ml fraction was collected. Concentration of the fraction in vacuo produced a clear, colorless oil which crystallized on

standing. The solid (mp 50-52°) was dissolved in ether, and the ethereal solution was treated with anhydrous magnesium sulfate and activated charcoal, filtered, and evaporated *in vacuo*. The dried (40°/0.20 mm) analytical sample of 1-*tert*-butyl-2,2-diphenylaziridine (*22*) melted at 50-52.5° and analyzed as follows: NMR SPECTRUM 12 (CCl_4) δ0.88 (singlet, 9H, *tert*-butyl), 2.16 (singlet, 2H, methylene), 7.0-7.5 (multiplet, 10H, aromatic); mass spectrum (70eV) *m/e* 194, 195 (base), 236, 251 (P^+).

Anal. Calcd for $C_{18}H_{21}N$: C, 86.01; H, 8.42; N, 5.57. Found: C, 86.01; H, 8.44; N, 5.53.

Authentic 1-tert-Butylamino-2,2-diphenylethylene (31). Into a 250-ml round-bottomed flask equipped with a reflux condenser and heating mantle was placed diphenylacetaldehyde (*33*, PCR, Inc., 19.6 g, 17.8 ml, 0.100 mol), *tert*-butylamine (14.6 g, 20 ml, 0.20 mol), molecular sieves (4A, *ca.* 10 g), and benzene (100 ml). The mixture was refluxed for two hours, and the resulting dark amber solution was cooled, treated with activated charcoal and anhydrous magnesium sulfate, and filtered through Celite. Concentration of the yellow filtrate *in vacuo* produced an oil, which was submitted to bulb-to-bulb distillation with a rotary evaporator (0.10 mm) and a Bunsen burner. The viscous, yellow distillate of 1-*tert*-butylamino-2,2-diphenylethylene (*31*, 20.0 g, 80%) solidified on standing. It was recrystallized four times from absolute methanol to furnish the analytical sample of

31* as white crystals: mp 77-83°; NMR SPECTRUM 13 (CCl_4) δ1.18 (singlet, 9H, tert-butyl), 3.66 (broad doublet, J=13 Hz, 1H, NH, exchanges with D_2O), 6.54 (broad doublet, J=13 Hz, 1H, vinyl, collapses to a singlet with D_2O), 7.00 (ca. singlet, 5H, aromatic), 7.22 (ca. singlet, 5H, aromatic).

Anal. Calcd for $C_{18}H_{21}N$: C, 86.01; H, 8.42; N, 5.57. Found: C, 85.88; H, 8.45; N, 5.61.

Treatment of 1-tert-Butyl-2,2-diphenylaziridine (22) with Florisil. 1-tert-Butylamino-2,2-diphenylethylene (31). A solution of crude 1-tert-butyl-2,2-diphenylaziridine (22, 0.50 g) in a mixed solvent of 20-40° petroleum ether and benzene (1:1, 10 ml) was applied to a 1.5x25-cm column of Florisil (Fisher, 100-200 mesh), packed in the same mixed solvent. The column was also eluted with the mixed solvent. The first 10-ml fraction that was eluted after the forerun was shown by nmr spectral comparison with authentic material to contain only 1-tert-butylamino-2,2-diphenylethylene (31, 0.04 g). The concentrated, second 10-ml fraction consisted of a mixture (0.10 g) of 31 and diphenylacetaldehyde.

Treatment of 1-tert-Butyl-2,2-diphenylaziridine (22) with Aqueous Perchloric Acid. 1,1-Diphenyl-2-tert-butylaminoethanol (32). Crude 1-tert-butyl-2,2-diphenylaziridine (22,

*Facile autoxidation of 31 to benzophenone and N-tert-butylformamide (by nmr spectral analysis) makes it imperative that light and oxygen be excluded from this compound.

0.25 g) was placed in a 50-ml round-bottomed flask, cooled to 0°, and treated with 5% aqueous perchloric acid (15 ml). The resulting mixture was washed with ether, and the water-soluble portion was neutralized at 0° with 5% aqueous sodium bicarbonate. The turbid system was then extracted into ether, and the ethereal phase was washed with saturated sodium chloride, treated with anhydrous magnesium sulfate, and concentrated *in vacuo*. The residue, a white solid (0.08 g), was shown by nmr spectroscopy (CCl_4) to contain predominantly 1,1-diphenyl-2-*tert*-butylaminoethanol (*32*):[16] δ1.08 (singlet, 9H, *tert*-butyl), 3.13 (singlet, 2H, methylene), 7.0-7.5 (multiplet, *ca*. 10H, aromatic).

Attempted Trapping of the Supposed Ylide 42 with Norbornene (43). A 10-ml round-bottomed flask was placed in a drybox and charged with a mixture of *N*-(benzhydrylidene)methyl-*tert*-butylaminium fluorosulfonate (*12a*, 0.35 g, 1.0 mmol) and norbornene (*43*, Aldrich, 0.94 g, 10 mmol). The mixture was stirred magnetically, and to it was added a solution of 0.26 *M* sodium bis(trimethylsilyl)amide (*30*) in benzene (5.5 ml, 1.4 mmol). The resulting slurry was stirred for one hour, and then filtered. Nmr spectral assay of the filtrate showed it to contain only the usual reaction product, 1-*tert*-butyl-2,2-diphenylaziridine (*22*), and unreacted norbornene.

Treatment of N-(Benzhydrylidene)dimethylaminium Fluorosulfonate (12b) with the Silylamide Base (30). A 300-ml

round-bottomed flask was placed in a drybox and charged with N-(benzhydrylidene)dimethylaminium fluorosulfonate (12b, 9.28 g, 30 mmol). A solution of sodium bis(trimethylsilyl)amide (30, 5.87 g, 32 mmol) in benzene (200 ml) was filtered onto the stirring salt. An immediate purple color developed, but it changed to brown during the 60-minute reaction time. Upon removal of the mixture from the drybox and exposure to the air, the mixture turned yellow. Filtration produced a clear, yellow solution, which darkened upon evaporation in vacuo at 35°. The residue was an amorphous, tan foam (6.26 g) whose nmr spectrum showed only broad, unidentified resonances.

Treatment of N-(Benzhydrylidene)methylallylaminium Fluorosulfonate (12c) with the Silylamide Base (30). A 100-ml round-bottomed flask was placed in a drybox and charged with a solution of sodium bis(trimethylsilyl)amide (30, 2.20 g, 12 mmol) in benzene (46 ml). The solution was stirred magnetically, and N-(benzhydrylidene)methylallylaminium fluorosulfonate (12c, 2.01 g, 6.0 mmol) was added over a period of 30 seconds. An immediate, red-brown color developed, but it rapidly faded to amber. Within 20 minutes, the mixture had turned dark brown. The flask was removed from the drybox and its contents were filtered. Evaporation of the filtrate in vacuo left a black gum, whose nmr spectrum showed only very diffuse signals.

The experiment was repeated on the same scale with only one equivalent of base 30 in benzene (23 ml), and the mixture was filtered after having stirred for only ten minutes. Half of the dark filtrate was washed with water, dried with molecular sieves, and evaporated in vacuo. The nmr spectrum of the residue was similar to that obtained from the previous experiment. In addition, it appeared that benzophenone was a major product of this work-up. The remainder of the filtrate was concentrated in vacuo (below 40°). The product was a black tar, which was not investigated further.

Treatment of N-(Benzhydrylidene)methylbenzhydrylaminium Fluorosulfonate (12d) with the Silylamide Base (30). A 1.5x15-cm test tube equipped with a magnetic stirrer was placed in a drybox and charged with N-(benzhydrylidene)-methylbenzhydrylaminium fluorosulfonate (12d, 0.23 g, 0.50 mmol). To the stirring solid was added a 0.26 M solution of sodium bis(trimethylsilyl)amide (30) in benzene (2.0 ml, 0.52 mmol). An immediate, green color developed, but it changed to tan almost instantaneously. The system was stirred at ambient temperature for five minutes, removed from the drybox, and filtered. The filtrate was concentrated in vacuo to produce a semisolid (0.38 g) whose nmr spectrum indicated the presence of a large quantity of benzophenone. A singlet of low intensity (δ2.32) may have been due to the presence of one of the anticipated products

(34 or 35, page 16), but the mixture was not investigated further.

Treatment of N-(Benzhydrylidene)methylanilinium Fluorosulfonate (12e) with the Silylamide Base (30). A 500-ml round-bottomed flask equipped with a magnetic stirrer was placed in a drybox and charged with N-(benzhydrylidene)-methylanilinium fluorosulfonate (12e, 11.14 g, 30.0 mmol) and sodium bis(trimethylsilyl)amide (30, 5.87 g, 32.0 mmol). To the stirring solids was added dry benzene (250 ml). An immediate, persistent, deep red color developed. The mixture was stirred for one hour, removed from the drybox, and filtered. The filtrate was evaporated in vacuo (35°), and the dark red residue was treated with pentane at -78°. Evaporation of the pentane-soluble decantate produced a clear, dark amber syrup (6.46 g), whose nmr spectrum (CCl_4) showed a species with a prominent singlet at δ2.77. In addition, smaller amounts of N-(benzhydrylidene)aniline (9e), benzophenone, and N-methylaniline were indicated. Only the latter was recovered (in toto, ca. 5% by weight of the crude mixture) by extraction of the mixture with 1% aqueous perchloric acid, followed by basification (5% aqueous sodium bicarbonate) and extraction into carbon tetrachloride. The species which resonated at δ2.77 was not recovered by silica gel chromatography (Silica Gel G, E. Merck AG, 20-40° petroleum ether eluent). It could not be purified by distillation (0.15 mm) or by alumina column chromatography (e.g.,

10% and 20% deactivated, benzene and 20-40° petroleum ether eluents).

General Procedure for the Preparation of the Aldimines (10). A mixture of benzaldehyde (Mallinckrodt, 10.6 g, 10.2 ml, 0.100 mol), the appropriate amine (0.100 mol), molecular sieves (4A, ca. 5 g), and benzene (100 ml) was refluxed for 2-5 hours in a 250-ml round-bottomed flask equipped with a reflux condenser and heating mantle. The mixture was then cooled, treated with anhydrous magnesium sulfate and activated charcoal, and filtered through Celite. The filtrate was concentrated in vacuo to furnish the crude aldimine (10). The products were purified, if necessary, by bulb-to-bulb distillation (ca. 0.05 mm) with a rotary evaporator and a Bunsen burner, or by recrystallization.

N-(Benzylidene)tert-butylamine (10a). N-(benzylidene)tert-butylamine (10a)[63] was prepared according to the general procedure from tert-butylamine (7.31 g, 10.0 ml, 0.100 mol). The distilled product (15.32 g, 95%) was a clear, colorless liquid whose nmr spectrum (CCl_4) showed δ1.25 (singlet, 9H, tert-butyl), 7.1-7.9 (multiplet, 5H, aromatic), 8.16 (singlet, 1H, N=CH).

N-(Benzylidene)methylamine (10b). This compound was prepared by a modification of the general aldimine synthesis. A mixture of benzaldehyde (21.2 g, 20.4 ml, 0.200 mol) and aqueous methylamine (MC/B, 40% w/v, 200 ml) was boiled

gently on a steam bath for 30 minutes in a 300-ml round-bottomed flask equipped with a reflux condenser. Excess methylamine was removed *in vacuo*, and the residue was treated with dichloromethane. The resulting solution was washed with water (3x100 ml), dried with anhydrous magnesium sulfate, and filtered. The filtrate was evaporated *in vacuo* to afford *N*-(benzylidene)methylamine (*10b*)[64] as a mobile, pale yellow oil (22.6 g, 95%); nmr (CCl_4) δ3.34 (doublet, *J*=1.6 Hz, 3H, CH_3), 7.1-7.8 (multiplet, 5H, aromatic), 8.03 (quartet, *J*=1.6 Hz, 1H, N=C*H*).

N-(Benzylidene)allylamine (*10c*). *N*-(Benzylidene)allylamine (*10c*)[65] was prepared in the usual manner from allylamine (11.4 g, 15.0 ml, 0.200 mol). The crude product was distilled to afford pure *10c* as a clear, colorless liquid (11.4 g, 79%) whose nmr spectrum (CCl_4) showed δ4.0-4.2 (multiplet, 2H, allyl), 4.9-5.4 (multiplet, 2H, $=CH_2$), 5.7-6.4 (multiplet, 1H, $CH_2=CH$), 7.1-7.8 (multiplet, 5H, aromatic), 8.07 (triplet, *J*=ca. 1.4 Hz, 1H, N=C*H*).

N-(Benzylidene)benzylamine (*10d*). Aldimine *10d* was prepared from benzylamine (Eastman, 10.7 g, 10.9 ml, 0.100 mol) according to the general procedure. Crude *N*-(benzylidene)-benzylamine (*10d*)[66] was isolated as a yellow oil in quantitative yield. It exhibited the following nmr spectrum (CCl_4): δ4.62 (doublet, *J*=1.5 Hz, 2H, benzyl), 7.1-7.8 (multiplet, 10H, aromatic), 8.10 (triplet, *J*=1.5 Hz, 1H, N=C*H*).

N-(Benzylidene)aniline (10e). N-(Benzylidene)aniline (10e) was prepared by a published procedure[67] from benzaldehyde (106 g, 102 ml, 1.00 mol) and aniline (93 g, 91 ml, 1.0 mol). The crude product was recrystallized from 85% aqueous ethanol and dried in a vacuum desiccator. The purified 10e (152 g, 84%) melted at 50-52° (lit.[67] 52°) and displayed the following nmr spectrum (CCl_4): δ6.9-8.0 (multiplet, 10H, aromatic), 8.27 (singlet, 1H, N=CH).

General Procedure for the Preparation of the Aldiminium Salts (14). All operations were performed in a drybox. Into an oven-dried flask equipped with a magnetic stirrer was placed a solution of the appropriate aldimine (10) in anhydrous ether. The flask was immersed in a Dry Ice-acetone bath, and to it was added (with stirring) methyl fluorosulfonate (11a, 1.8 equivalents). Except as noted, a voluminous white precipitate formed almost immediately after the addition of 11a. The cold bath was removed, and the mixture was allowed to stir overnight at ambient temperature. The aldiminium salt was then collected by filtration, washed with ether, dried, weighed, and stored in the drybox.

N-(Benzylidene)methyl-tert-butylaminium Fluorosulfonate (14a). The general alkylation procedure was followed with N-(benzylidene)tert-butylamine (10a, 32.3 g, 0.200 mol), methyl fluorosulfonate (11a, 42.4 g, 30 ml, 0.37 mol), and ether (200 ml), in a 500-ml round-bottomed flask. The thick, white precipitate that resulted was allowed to warm to ambient

temperature, and diluted with ether (100 ml) to facilitate stirring. The usual work-up afforded crude N-(benzylidene)-methyl-tert-butylaminium fluorosulfonate (14a, 54.7 g, 99%) as a white powder, which melted at ca. 154-173° and showed NMR SPECTRUM 7 (SO_2): δ1.73 (singlet, 9H, tert-butyl), 3.83 (doublet, J=ca. 1.0 Hz, 3H, NCH_3), 7.6-8.1 (multiplet, 5H, aromatic), 9.03 (broad pseudosinglet, 1H, N=CH).

N-(Benzylidene)dimethylaminium Fluorosulfonate (14b). Aldiminium salt 14b was prepared in an inert atmosphere, but not in a drybox as per the general procedure. An oven-dried 500-ml three-necked round-bottomed flask was equipped with a gas inlet, drying tube, and magnetic stirrer. The flask was charged with N-(benzylidene)methylamine (10b, 11.9 g, 0.100 mol) and anhydrous ether (100 ml), cooled with an ice bath, and purged with dry nitrogen. At 0°, methyl fluorosulfonate (11a, 21 g, 15 ml, 0.18 mol) was added, and the immediate, white precipitate was treated with additional ether (100 ml) to facilitate stirring. The thick mixture was stirred at 0° for one hour and then transferred to a drybox, where it was filtered, washed with ether, and dried. The crude N-(benzylidene)dimethylaminium fluorosulfonate (14b) was isolated as a white powder (22.3 g, 96%) which melted at 80-88.5° (sealed capillary). NMR SPECTRUM 8 (SO_2) showed δ3.88 (doublet, J=ca. 1.3 Hz, 3H, CH_3), 3.98 (doublet, J=ca. 1.0 Hz, 3H, CH_3), 7.6-8.1 (multiplet, 5H, aromatic), 8.9-9.0 (multiplet, 1H, N=CH).

N-(Benzylidene)methylallylaminium Fluorosulfonate (14c). The general alkylation procedure was followed with N-(benzylidene)allylamine (10c, 7.26 g, 0.050 mol), methyl fluorosulfonate (11a, 10.6 g, 7.5 ml, 0.093 mol), and ether (50 ml), in a 200-ml round-bottomed flask. The usual work-up furnished N-(benzylidene)methylallylaminium fluorosulfonate (14c, 12.81 g, 99%) as a mixture of two isomers (ca. 20:1). From NMR SPECTRUM 9 (SO_2), the major isomer showed δ3.80 (doublet, J=ca. 1.4 Hz, CH_3), 4.70 (doublet, J=6.0 Hz, allyl), 5.5-6.5 (multiplet, vinyl), 7.5-8.1 (multiplet, aromatic), 8.98 (broad pseudosinglet, N=CH). The minor isomer showed a methyl doublet (J=ca. 1.2 Hz) at δ3.88.

N-(Benzylidene)methylbenzylaminium Fluorosulfonate (14d). The general alkylation procedure was modified for the preparation of salt 14d. A 100-ml round-bottomed flask was placed in a drybox and charged with N-(benzylidene)-benzylamine (10d, 5.86 g, 0.030 mol) and dry chloroform (50 ml). The flask was immersed in a Dry Ice-acetone bath, and to the stirring solution was added methyl fluorosulfonate (11a, 7.1 g, 5.0 ml, 0.062 mol). The system was allowed to warm to ambient temperature, whereupon the product separated from the mixture as an oil. The supernatant was decanted from the oil, and the oil was washed with ether and then carbon tetrachloride. The crude N-(benzylidene)methylbenzylaminium fluorosulfonate (14d) was shown by nmr spectroscopy

(DMSO-d_6) to be a mixture (ca. 4:1) of isomers: major, δ3.72 (doublet, J<1.0 Hz, CH_3), 5.38 (pseudosinglet, benzyl), 7.4-8.3 (multiplet, aromatic), 9.60 (broad pseudosinglet, N=CH); minor, δ3.80 (doublet, J<1.0 Hz, CH_3), 5.20 (pseudosinglet, benzyl), 7.4-8.3 (multiplet, aromatic), 9.35 (broad pseudosinglet, N=CH).

N-(Benzylidene)methylanilinium Fluorosulfonate (14e). N-(Benzylidene)aniline (10e, 18.1 g, 0.100 mol), methyl fluorosulfonate (11a, 21.2 g, 15 ml, 0.19 mol), and ether (100 ml) were used to prepare aldiminium salt 14e, according to the general procedure. N-(Benzylidene)methylanilinium fluorosulfonate (14e) was isolated as a white powder (28.9 g, 98%) which melted at 141-147°. Its NMR SPECTRUM 10 (SO_2) showed the presence of two isomers (ca. 4:1): major, δ4.22 (doublet, J=1.0 Hz, CH_3), 7.3-8.0 (multiplet, aromatic), 9.0-9.2 (multiplet, N=CH); minor, δ4.33 (doublet, J=1.1 Hz, CH_3).

Authentic N-Methyl-N-tert-butylbenzamide (47). A 25-ml round-bottomed flask equipped with a magnetic stirrer was charged with methyl-tert-butylamine hydrochloride[23] (1.24 g, 0.010 mol). The solid was stirred and cooled with an ice bath, and to it was added benzoyl chloride (Eastman, 1.57 g, 1.3 ml, 0.011 mol) and 10% aqueous sodium hydroxide (8 ml, 0.020 mol). After stirring for five minutes, the mixture was extracted with carbon tetrachloride. The organic extract was washed with water and saturated sodium chloride, dried with anhydrous magnesium sulfate, and concentrated in vacuo. The

off-white residue (3.35 g) was freed of unreacted benzoyl chloride by washing with cold pentane. The crude N-methyl-N-tert-butylbenzamide (47, 0.98 g, 51%) melted at 60-65°. Two recrystallizations from hot pentane afforded the analytical sample of 47: mp 80-82°; ir (KBr) ν1625 cm^{-1}; NMR SPECTRUM 14 (CCl_4) δ1.42 (singlet, 9H, tert-butyl), 2.75 (singlet, 3H, NCH_3), 7.1-7.4 (multiplet, 5H, aromatic); mass spectrum (70eV) m/e 77, 105 (base), 106, 176, 191 (P^+).

Anal. Calcd for $C_{12}H_{17}NO$: C, 75.35; H, 8.96; N, 7.32. Found: C, 75.48; H, 9.00; N, 7.23.

Decomposition of N-(Benzylidene)methyl-tert-butylaminium Fluorosulfonate (14a) with Aqueous Base, and Derivatization of Product 46. N-Methyl-N-tert-butylbenzamide (47). A mixture of N-(benzylidene)methyl-tert-butylaminium fluorosulfonate (14a, 8.26 g, 30 mmol) and 10% aqueous sodium hydroxide (24 ml, 60 mmol) was stirred magnetically in a 100-ml round-bottomed flask. To the mixture was added benzoyl chloride (4.64 g, 3.8 ml, 33 mmol). The turbid, white system was stirred for 15 minutes, and then cooled with an ice bath. The resulting precipitate was filtered and washed with water, and then with cold 20-40° petroleum ether. The dried, white powder was shown (by nmr spectroscopy and mixture melting point determination with authentic material) to be N-methyl-N-tert-butylbenzamide (47, 2.08 g, 37%, mp 78.5-81°). The petroleum ether wash afforded an additional crop of amide 47 (1.41 g, 25%).

Authentic 1-tert-Butyl-2-phenylaziridine (39). 1-tert-Butyl-2-phenylaziridine (39) was prepared according to the procedure of Moyer.[16] The compound exhibited the following nmr spectrum in carbon tetrachloride: δ0.96 (singlet, 9H, tert-butyl), 1.44 (d of doublets, 1H, H_{cis}), 1.73 (d of doublets, 1H, H_{trans}), 2.46 (d of doublets, 1H, benzyl), 7.0-7.3 (multiplet, 5H, aromatic).

Treatment of N-(Benzylidene)methyl-tert-butylaminium Fluorosulfonate (14a) with Potassium tert-Butoxide (28). Isolation and Purification of Aminoether 48. N-(Benzylidene)methyl-tert-butylaminium fluorosulfonate (14a, 13.77 g, 50 mmol) was placed in a 500-ml round-bottomed flask in a drybox. The flask was immersed in a Dry Ice-acetone bath, and to salt 14a was added, with magnetic stirring, potassium tert-butoxide (28, 5.83 g, 52 mmol) and anhydrous ether (300 ml). The cold bath was removed, and the pale yellow slurry was stirred for one hour. The mixture was then filtered through Celite, and the filtrate was removed from the drybox and evaporated in vacuo. The residue thus obtained was a clear, viscous, yellow oil (5.73 g) whose nmr spectrum indicated (vide infra) a product distribution of aminoether (48):aldimine (10a):PhCHO:dimers (50 + 52)::80:12:5:3 mol-%.

The crude mixture was distilled at reduced pressure (0.05 mm) and the fraction which boiled at 123-125° (0.98 g) was redistilled. The second distillation afforded the analytical sample of aminoether 48: bp 73°/0.01 mm; NMR

SPECTRUM 15 (CCl_4) δ1.15 (singlet, 9H, tert,butyl), 1.23 (singlet, 9H, tert-butyl), 2.21 (singlet, 3H, NCH_3), 5.65 (singlet, 1H, benzyl), 7.0-7.6 (multiplet, 5H, aromatic); mass spectrum (70eV) m/e 59 (base, 72, 77, 105, 106 (P^+ 249 unobsd).

Anal. Calcd for $C_{16}H_{27}NO$: C, 77.05; H, 10.91; N, 5.62. Found: C, 77.02; H, 10.95; N, 5.64.

Decomposition of Aminoether 48 with Deuterium Oxide. Deuterium oxide (MSD of Canada, Ltd., min 99.7 atom-% D, one drop) was added to the sample of aminoether 48 (still in carbon tetrachloride) that was used to obtain NMR SPECTRUM 15. There was no spectral evidence for reaction within 15 minutes of the addition. However, it was shown by integrating the singlets at δ5.58 (48, benzyl) and 9.85 (PhCHO) that about half of the aminoether had decomposed after four hours. Complete decomposition of 48 was accomplished overnight. The reaction products, which were produced in equimolar quantities, were benzaldehyde, tert-butyl deuteroxide (t-BuOD), and the deuterated amine DN(Me)t-Bu (49). These products were identified by spiking the mixture with authentic samples, and noting their equivalence in the nmr spectrum. Authentic 49 was generated from methyl-tert-butylamine (46, vide supra) by in situ deuterium exchange.

Decomposition of Aminoether 48 with Aqueous Base, and Derivatization of Product 46. N-Methyl-N-tert-butylbenzamide (47). A mixture of aminoether 48 (1.00 g, 4.0 mmol)

and 10% aqueous sodium hydroxide (24 ml, 4 mmol) was stirred magnetically in a 1.5x15-cm test tube. Benzoyl chloride (0.62 g, 0.51 ml, 4.4 mmol) was added, and the turbid, white mixture was stirred for five minutes. The system was extracted with carbon tetrachloride, and the organic extract was washed with saturated sodium chloride, dried with molecular sieves (4A), and evaporated *in vacuo*. The crude *N*-methyl-*N*-*tert*-butylbenzamide (*47*, 0.32 g, 42%) was recrystallized from hot pentane, and the purified amide was found to melt at 79-81°. Its mixture melting point with authentic *47* was not depressed. The structure assignment was further confirmed by nmr spectral analysis.

Treatment of N-(Benzylidene)methyl-tert-butylaminium Fluorosulfonate (14a) with Sodium Bis(trimethylsilyl)amide (30). Isolation and Purification of Diaminostilbene 52 and the Major and Minor Aminomethylaziridine Isomers (50). A 1000-ml round-bottomed flask was placed in a drybox and charged with sodium bis(trimethylsilyl)amide (*30*, 22.01 g, 120 mmol) and dry benzene (460 ml). The system was stirred magnetically until solution was effected, at which time *N*-(benzylidene)methyl-*tert*-butylaminium fluorosulfonate (*14a*, 16.52 g, 60.0 mmol) was added. An immediate, intense yellow color was produced, but it lightened appreciably within five minutes after the addition of *14a*. The slurry was stirred for one hour, removed from the drybox, and filtered. The

filtrate was evaporated at reduced pressure, and the residue was treated with hexane, activated charcoal, and anhydrous magnesium sulfate. The mixture was filtered, and the filtrate was concentrated *in vacuo*. The nmr spectrum (benzene-d_6) of the resulting dark oil (13.77 g) indicated (*vide infra*) the presence of the diaminostilbene **52** and the major and minor isomers of the aminomethylaziridine **50**, in the approximate ratio of 1.0:6.7:1.3. Also present were smaller amounts of *N*-(benzylidene)*tert*-butylamine (**10a**) and several unidentified silylated species (1-6 Hz downfield from TMS).

A filtered solution of the crude product mixture (12.88 g) in benzene (100 ml) was chromatographed on a 2.5x65-cm column of silica gel (Baker, 60-200 mesh) packed in 30-60° petroleum ether. The column was eluted initially with benzene. The first six 10-ml fractions were combined and concentrated *in vacuo* to produce the crude diaminostilbene (**52**) as a yellow powder. Recrystallization of the material from 95% ethanol, followed by sublimation (95-100°/0.025 mm), afforded the analytical sample of α,α'-bis(methyl-*tert*-butylamino)stilbene, **52**: mp 109.5-114.5°; NMR SPECTRUM 19 (CCl_4) δ0.91 (singlet, 18H, *tert*-butyl), 2.35 (singlet, 6H, NCH_3), 7.0-7.5 (multiplet, 10H, aromatic); mass spectrum (70eV) *m/e* 41 (base), 69, 149 (P^+ 351 unobsd).

Anal. Calcd for $C_{24}H_{34}N_2$: C, 82.23; H, 9.78; N, 7.99. Found: C, 81.96; H, 9.86; N, 8.01.

An additional 40-ml fraction was eluted from the column, and was shown by tlc analysis (benzene eluent) to contain a

mixture of the diaminostilbene 52* (R_f 0.7) and the major aminomethylaziridine isomer (R_f 0.0-0.4). The next 100-ml fraction was evaporated in vacuo to afford the crude, major isomer of 50 (4.01 g) as a pale yellow powder. The material was purified by recrystallization from 95% ethanol, and sublimed (95°/0.025 mm). The off-white sample of major-50 melted at 117-119°, and analyzed as follows: NMR SPECTRUM 16 (CCl_4) δ0.71 (singlet, 9H, tert-butyl), 0.89 (singlet, 9H, tert-butyl), 1.74 and 1.98 (doublets, J=1.4 Hz, 2H, methylene), 2.33 (singlet, 3H, NCH_3), 4.48 (singlet, 1H, benzyl), 7.0-7.5 (multiplet, 10H, aromatic); mass spectrum (70eV) m/e 41, 42, 120, 176 (base), 351 (weak P^+).

Anal. Calcd for $C_{24}H_{34}N_2$: C, 82.23; H, 9.78; N, 7.99. Found: C, 82.13; H, 9.79; N, 8.06.

A final 350 ml of benzene was eluted, and the column was flushed with methanol. The first 10-ml fraction of methanol was discarded. The next 250-ml fraction was evaporated in vacuo, and the residue was dissolved in carbon tetrachloride. The solution was washed with saturated sodium chloride, dried with anhydrous magnesium sulfate, and concentrated in vacuo. The crude minor aminomethylaziridine isomer was obtained as a viscous, amber oil (0.91 g), which was crystallized at low temperature. The analytical

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*A very sensitive test for contamination by diaminostilbene 52 is its brilliant yellow-green fluorescence under ultraviolet light. The pure aminomethylaziridine isomers (50) do not fluoresce.

sample of minor-50, after recrystallization from 95% ethanol and sublimation (ca. 76°/0.025 mm), melted at 77.5-79°; NMR SPECTRUM 17 (CCl_4) δ0.77 (singlet, 9H, tert-butyl), 0.83 (singlet, 9H, tert-butyl), 1.13 and 1.68 (doublets, J=1.4 Hz, 2H, methylene), 2.78 (singlet, 3H, NCH_3), 4.13 (singlet, 1H, benzyl), 7.0-7.5 (multiplet, 10H, aromatic); mass spectrum (70eV) m/e 57, 72, 119, 206 (base), 351 (weak P^+).

Anal. Calcd for $C_{24}H_{34}N_2$: C, 82.23; H, 9.78; N, 7.99. Found: C, 82.10; H, 9.82; N, 8.00.

Pyrolyses of the Major and Minor Isomers of Aminomethylaziridine 50. A 1.7x90-mm melting point capillary tube was filled to a depth of about 15 mm with the major isomer of aminomethylaziridine 50. The capillary tube was sealed, and then heated in a Thomas-Hoover Unimelt capillary melting point apparatus (ca. 10 deg/min). The sample was observed to melt at 114.5-117°; the melt gradually became yellow (ca. 200°), and turned orange upon continued heating. When the oil bath had reached 250°, the capillary was withdrawn, cleaned with carbon tetrachloride, and cracked open. The section of the capillary which contained the orange melt was inserted into an nmr sample tube, and carbon tetrachloride (ca. 0.5 ml) and the tetramethylsilane standard were added. The nmr sample tube was capped and shaken to leach the melt from the broken capillary. The nmr spectrum of the resulting solution indicated that the predominant pyrolysis

product of major-50 was the diaminostilbene 52, in addition to lesser amounts of the starting material and the minor isomer (8.6:1). These spectral assignments were supported by tlc assay.

The pyrolysis was repeated with the minor isomer of aminomethylaziridine 50. This compound melted at 77-80°, but showed the same color changes as did major-50. The nmr spectrum of the melt also indicated that diaminostilbene 52 was the predominant pyrolysis product. Compound 52 was accompanied by smaller amounts of the starting isomer (minor-50) and the major isomer (1:1.5).

Attempted Trapping with Norbornene (43). A 25-ml round-bottomed flask was placed in a drybox and charged with N-(benzylidene)methyl-tert-butylaminium fluorosulfonate (14a, 0.41 g, 1.5 mmol), norbornene (43, 1.41 g, 15 mmol) and dry benzene (5 ml). The mixture was stirred magnetically, and to it was added a 0.26 M solution of sodium bis(trimethylsilyl)amide (30) in benzene (11.5 ml, 3.0 mmol). The system was stirred at ambient temperature for one hour, removed from the drybox, and filtered through Celite. The filtrate was concentrated in vacuo (thereby removing any unreacted norbornene), and the resulting amber semisolid (0.45 g) was shown by nmr spectral assay to contain only the usual reaction products (vide supra).

Stability of 1-tert-Butyl-2-phenylaziridine (39) to the Deprotonation Conditions. 1-tert-Butyl-2-phenylaziridine

(39, ca. 75 mg) was dissolved in benzene-d_6 (ca. 1 ml) in an nmr sample tube. Sodium bis(trimethylsilyl)amide (30, ca. 100 mg) was then added. The mixture was shaken mechanically for one hour, and then treated with deuterium oxide (3 drops). The sample tube was shaken again and centrifuged. The nmr spectrum of the organic layer indicated that no deuterium exchange had taken place.

In a related experiment, a mixture of 1-tert-butyl-2-phenylaziridine (39, 0.26 g, 1.5 mmol) and a 0.26 M solution of sodium bis(trimethylsilyl)amide (30) in benzene (5.8 ml, 1.5 mmol) was stirred magnetically in a 10-ml round-bottomed flask, in a drybox. After one hour, N-(benzylidene)methyl-tert-butylaminium fluorosulfonate (14a, 0.41 g, 1.5 mmol) was added. The slurry was stirred for an additional 60 minutes, removed from the drybox, and filtered. The filtrate was concentrated in vacuo to produce a clear, dark amber liquid (0.57 g), whose nmr spectrum indicated only the usual mixture of products (vide supra) and the intact 1-tert-butyl-2-phenylaziridine (39).

Stability of the Major Isomer of Aminomethylaziridine 50 to Sodium Bis(trimethylsilyl)amide (30). A 25-ml round-bottomed flask was placed in a drybox and charged with the major isomer of 50 (0.21 g, 0.60 mmol), sodium bis(trimethylsilyl)amide (30, 0.44 g, 2.4 mmol), and dry benzene (10 ml). The solution was stirred magnetically for one hour, removed from the drybox, and washed with water. The

benzene layer was treated with activated charcoal and anhydrous magnesium sulfate, filtered, and concentrated *in vacuo*. The resulting pale yellow powder was shown by nmr spectroscopy to be the recovered aminomethylaziridine, *major*-50 (0.19 g, 91%).

Authentic α,α'-Bis(dimethylamino)stilbene Isomers (53). The mixture of *E*- and *Z*-isomers of compound 53 was prepared from α-(dimethylamino)phenylacetonitrile[68] by a published procedure.[24] The crude product mixture was shown by nmr spectroscopy to contain approximately equal amounts of the two isomers. Although the isomers were not separated, the mixture was purified by double distillation (109-110°/0.025 mm) and two column chromatographies (Fisher Alumina, Basic, Brockman Activity I, benzene eluent). Data taken from NMR SPECTRUM 18 (CCl_4), together with the assignments that were made in Chapter I (p 29), are as follows: *entgegen* (53a) δ2.28 (singlet, 12H, CH_3), 7.18 (*ca*. singlet, 10H, aromatic); *zusammen* (53b) δ2.67 (singlet, 12H, CH_3), 6.88 (*ca*. singlet, 10H, aromatic).

Treatment of *N*-(Benzylidene)dimethylaminium Fluorosulfonate (14b) with the Silylamide Base (30). Products 51 and 53. A 200-ml round-bottomed flask was placed in a drybox and charged with *N*-(benzylidene)dimethylaminium fluorosulfonate (14b, 3.50 g, 0.015 mol) and sodium bis(trimethylsilyl)amide (30, 5.50 g, 0.030 mol). To the stirring mixture was added dry benzene (115 ml). A brilliant orange color developed

immediately, but it faded to yellow within one minute after the rapid addition of benzene. The mixture was stirred at ambient temperature for one hour, removed from the drybox, and filtered through Celite. Concentration of the filtrate *in vacuo* produced a dark semisolid (4.43 g) whose nmr spectrum (CCl_4) indicated the presence of the supposed aminomethylaziridine 51 [δ2.02 and 2.13 (doublets, methylene), 2.20 (amino-CH_3's), 4.45 (singlet, benzyl)], and about an equal amount of the diaminostilbene isomers 53a and 53b (*ca.* 1:1). In addition, there were many other unidentified resonances present in the spectrum.

In a typical separation attempt, the crude product mixture was dissolved in benzene (15 ml) and applied to a 2x20-cm column of basic alumina (Fisher, Brockman Activity I, 80-200 mesh) packed in 30-60° petroleum ether. The first (orange) 20-ml fraction of eluate was shown by nmr spectroscopy to contain the mixture of the α,α'-bis(dimethylamino)-stilbene isomers (53, 0.35 g). The supposed aminomethylaziridine 51 was not eluted from the column, even after flushing with methanol.

Treatment of N-(Benzylidene)methylallylaminium Fluorosulfonate (14c) with the Silylamide Base (30). A 100-ml round-bottomed flask was placed in a drybox and charged with a solution of sodium bis(trimethylsilyl)amide (30, 2.20 g, 12.0 mmol) in dry benzene (46 ml). To the stirring solution was added N-(benzylidene)methylallylaminium fluorosulfonate (14c, 1.56 g, 6.0 mmol), over a period of 30

seconds. A brilliant yellow color developed immediately upon addition of the salt, but it changed to orange within one hour. The mixture was removed from the drybox at this time and filtered. The filtrate was evaporated *in vacuo* to produce a syrup (0.76 g), whose nmr spectrum indicated that it contained a very complex mixture. The aldimines *10b* and *10c* were *not* detected by this assay. Chromatography on silica gel (Baker, 60-200 mesh, benzene-petroleum ether eluent) afforded benzaldehyde as the only identified product.

Treatment of N-(Benzylidene)methylbenzylaminium Fluorosulfonate (14d) with the Silylamide Base (30). A 100-ml round-bottomed flask equipped with a magnetic stirrer was placed in a drybox and charged with crude *N*-(benzylidene)-methylbenzylaminium fluorosulfonate (*14d*, 1.37 g, 4.5 mmol). Onto the stirring oil was filtered a solution of sodium bis(trimethylsilyl)amide (*30*, 0.94 g, 5.1 mmol) in benzene (30 ml). The mixture was stirred at ambient temperature for 75 minutes, and then filtered outside of the drybox. The filtrate was concentrated *in vacuo*, and the residue was dissolved in carbon tetrachloride. The solution thus obtained was dried with anhydrous magnesium sulfate and evaporated to a clear, orange oil (0.87 g). Nmr spectral data indicated that *N*-(benzylidene)benzylamine (*10d*) was present in the mixture in a relatively low concentration. In addition, methylbenzylamine (*54*) was identified as a minor

component of the crude oil, by an acid-base extraction. To the residue was added 5% aqueous perchloric acid. The aqueous phase was washed with dichloromethane, basified at 0° with 10% aqueous sodium hydroxide, and extracted back into dichloromethane. The organic layer was separated, dried with anhydrous magnesium sulfate, and concentrated *in vacuo*. The infrared and nmr spectra of the residual pale yellow oil compared favorably with those of authentic[25] methylbenzylamine (*54*).

Treatment of N-(Benzylidene)methylanilinium Fluorosulfonate (14e) with the Silylamide Base (30). *N*-(Benzylidene)-methylanilinium fluorosulfonate (*14e*, 8.86 g, 30 mmol) was placed in a 1000-ml round-bottomed flask in a drybox, and onto it was filtered (with magnetic stirring) sodium bis-(trimethylsilyl)amide (*30*, 11.74 g, 64 mmol) in dry benzene (400 ml). An immediate, orange color developed. The color faded rapidly to yellow, and then returned to orange. The slurry was stirred for one hour, removed from the drybox, filtered, and concentrated *in vacuo*. The residue (8.04 g) was a dark, viscous syrup, whose nmr spectrum indicated the presence of several silylated species (0.2-0.6 ppm downfield from the tetramethylsilane standard), some *N*-(benzylidene)aniline (*10e*), and several unidentified species having singlets in the region δ2.6-2.9.

N-Methylbenzanilide (101). Into a 500-ml round-bottomed flask equipped with a magnetic stirrer was placed benzoyl

chloride (33.7 g, 28.0 ml, 0.240 mol), N-methylaniline (freshly distilled, 24.0 g, 24.4 ml, 0.224 mol), and 10% aqueous sodium hydroxide (180 ml). The mixture was stirred for 30 minutes and then cooled with an ice bath. Water was added and the product was extracted into dichloromethane. The organic layer was washed with water and saturated sodium chloride, treated with anhydrous magnesium sulfate and activated charcoal, and filtered through Celite. The filtrate was evaporated *in vacuo* to produce a quantitative yield of the crude N-methylbenzanilide (101)[69] as a clear, viscous oil, which solidified slowly to a low-melting solid. The nmr spectrum (CCl_4) of 101 showed δ3.38 (singlet, 3H, CH_3), 6.8-7.4 (multiplet, 10H, aromatic).

N-(α-Ethoxybenzylidene)methylanilinium Triflate (98). A 100-ml round-bottomed flask was placed in a drybox and charged with N-methylbenzanilide (101, 6.33 g, 0.030 mol). Ethyl triflate (Willow Brook Laboratories, Inc., 98%, 10 ml) was then added with magnetic stirring. The reaction was exothermic. It produced a thick, white precipitate within 15 minutes after the addition of the alkylating agent. Anhydrous ether (50 ml) had to be added to facilitate stirring. The mixture was stirred for an additional 10 minutes, removed from the drybox, and filtered. The collected solid was washed with ether and dried in a vacuum desiccator to afford crude 98 (10.6 g, 91%) as a white

powder, melting at 116.5-120°. The material was recrystallized from ethanol-ether, prior to its use in the deprotonation experiment.

The analytical sample of N-(α-ethoxybenzylidene)-methylanilinium triflate (98) resulted from four additional ethanol-ether recrystallizations, and consisted of white needles which melted at 116-119.5°. Data taken from NMR SPECTRUM 20 (SO_2) clearly indicated the presence of two isomers (ca. 7:1): (major isomer) δ1.55 (triplet, J=7 Hz, 3H, CH_2CH_3), 3.88 (singlet, 3H, NCH_3), 4.50 (quartet, J=7 Hz, 2H, CH_2CH_3), 7.31 (singlet, 5H, aromatic), 7.46 (singlet, 5H, aromatic); and (minor isomer) δ1.22 (triplet, J=7 Hz, 3H, CH_2CH_3), 3.57 (singlet, 3H, NCH_3), 4.33 (quartet, J=7 Hz, 2H, CH_2CH_3), 7.60 (singlet, 5H, aromatic), 7.82 (singlet, 5H, aromatic). The mass spectrum (70eV) showed m/e 51, 77, 105 (base), 211 (P^+ 389 unobsd).

Anal. Calcd for $C_{17}H_{18}F_3NO_4S$: C, 52.44; H, 4.66; N, 3.60. Found: C, 52.36; H, 4.79; N, 3.62.

Authentic N-Phenylbenzimidoyl Chloride (103). A solution of benzanilide[70] (5.92 g, 0.030 mol) in thionyl chloride (50 g, 30 ml, 0.42 mol) was refluxed for 90 minutes in a 100-ml round-bottomed flask equipped with a reflux condenser, drying tube, and heating mantle. Unreacted thionyl chloride was removed at reduced pressure, and the mobile, yellow residue was purified by bulb-to-bulb distillation with a rotary evaporator (ca. 0.10 mm) and gentle heat from a

Bunsen burner. Upon cooling, the pure N-phenylbenzimidoyl chloride (103, 5.64 g, 87%) crystallized as a pale yellow solid: mp 40-41.5° (lit.[71] 39-40°); nmr ($SOCl_2$) δ6.9-8.3 (multiplet, aromatic).

Treatment of N-Methylbenzanilide (101) with Thionyl Chloride. N-Phenylbenzimidoyl Chloride (103). Into a 25-ml round-bottomed flask was placed N-methylbenzanilide (101, 2.11 g, 0.010 mol) and thionyl chloride (Eastman, 17g, 10 ml, 0.14 mol). The mixture was refluxed (overnight) until the evolution of sulfur dioxide had ceased. Unreacted thionyl chloride was removed at reduced pressure, and the resulting clear, orange oil (2.27 g) was shown by nmr spectral comparison with authentic material to contain largely N-phenylbenzimidoyl chloride (103).

N-(α-Chlorobenzylidene)methylanilinium Fluorosulfonate (99). A 1.5x15-cm test tube was charged with N-phenylbenzimidoyl chloride (103, 2.16 g, 0.010 mol) in a drybox. To it was added methyl fluorosulfonate (11a, 7.06 g, 5.0 ml, 0.062 mol), with magnetic stirring. The resulting yellow solution became opaque after four minutes, and a solid precipitated ten minutes later. After stirring for an additional 25 minutes, the mixture was treated with anhydrous ether (50 ml). The crude N-(α-chlorobenzylidene)methylanilinium fluorosulfonate (99) was collected by filtration in the drybox and washed with ether. The white solid (1.52 g, 46%) melted broadly (145-158°), gave a positive silver nitrate

test for halide, and showed NMR SPECTRUM 21 (DMSO-d_6): δ3.38 (singlet, 3H, CH_3), 7.22 (singlet, ca. 5H, aromatic), 7.27 (singlet, ca. 5H, aromatic).

Treatment of N-(α-Ethoxybenzylidene)methylanilinium Triflate (98) with Potassium tert-Butoxide (28). A dry, 50-ml three-necked round-bottomed flask was equipped with a gas inlet, drying tube, serum cap, and magnetic stirrer, and was placed in a drybox. The flask was charged with a mixture of N-(α-ethoxybenzylidene)methylanilinium triflate (98, 1.17 g, 3.0 mmol) and potassium tert-butoxide (28, 0.35 g, 3.5 mmol). The closed system was quickly removed from the drybox, purged with dry nitrogen, and cooled with a Dry Ice-acetone bath. Anhydrous ether (20 ml) was then added to the stirring mixture via a hypodermic syringe, over a period of five minutes. The resulting white slurry was stirred at -78° for 20 minutes, and then was allowed to stir for three hours at room temperature. The mixture was filtered, and the filtrate was evaporated in vacuo to produce a clear, mobile, amber oil (0.81 g). The nmr spectrum (CCl_4) of the oil indicated it to be a mixture of ethyl benzoate, N-methylaniline [δ2.62 (singlet, CH_3)] and N-methylbenzanilide [101, δ3.34 (singlet, CH_3)], in a ratio of 1:1:0.8. The qualitative assay was confirmed by comparison of the thin-layer chromatogram (benzene eluent) of the mixture with those of the authentic components.

Treatment of N-(α-Ethoxybenzylidene)methylanilinium Triflate

(98) with Sodium Bis(trimethylsilyl)amide (30). A dry, three-necked round-bottomed flask was fitted with a gas inlet, drying tube, serum cap, and magnetic stirrer, and was placed in a drybox. The flask was then charged with N-(α-ethoxybenzylidene)methylanilinium triflate (98, 3.89 g, 0.010 mol). The system was closed, removed from the drybox, cooled with an ice bath, and purged with dry nitrogen. A 20-ml hypodermic syringe was then used to add a 0.26 M solution of sodium bis(trimethylsilyl)-amide (30) in benzene (prepared and stoppered in the drybox, 42 ml, 0.011 mol) to the stirring salt 98. The addition time was 3.5 minutes. The resulting orange slurry was stirred at 0° for five minutes, and then allowed to warm to room temperature. Ether (ca. 50 ml) was added, the mixture was filtered, and the filtrate was concentrated in vacuo to produce an opaque, viscous, amber oil, which could not be crystallized. The nmr spectrum of the oil indicated that it was a complex mixture. A solution of the oil in benzene was chromatographed on a 2x26-cm column of 10% deactivated Fisher Adsorption Alumina (80-200 mesh) packed in 20-40° petroleum ether. Elution with benzene failed to separate any of the components of the crude reaction mixture to the extent that they could be identified.

Treatment of N-(α-Chlorobenzylidene)methylanilinium Fluorosulfonate (99) with Sodium Bis(trimethylsilyl)amide (30). N-(α-Chlorobenzylidene)methylanilinium fluorosulfonate (99,

0.99 g, 3.0 mmol) was placed in a 25-ml round-bottomed flask in a drybox, and to it was added (with magnetic stirring) a 0.26 M solution of sodium bis(trimethylsilyl)-amide (30) in benzene (15 ml, 3.9 mmol). The immediate, persistent, dark brown color that developed was accompanied by the liberation of heat. The system was stirred for 3.5 hours, during which time no visible change took place. The mixture was removed from the drybox, treated with carbon tetrachloride, anhydrous magnesium sulfate, and activated charcoal, and filtered through Celite. Concentration of the filtrate in vacuo produced a dark brown oil (0.63 g). Assay of the oil by nmr spectroscopy (CCl_4) suggested that N-methylbenzanilide [101, δ3.37 (singlet, CH_3)] was a component of the mixture, in addition to at least five other products. The latter conclusion was supported by tlc analysis (benzene eluent). Attempts to separate or identify components of the mixture on a 1.5x11-cm column of 5% deactivated Fisher Adsorption Alumina (80-200 mesh) were unsuccessful.

2-Phenyl-1-azirine (100a). 2-Phenyl-1-azirine (100a) was prepared according to the method of Hortmann et al.[52a] in 43% overall yield from styrene: nmr (CCl_4) δ1.63 (singlet, 2H, methylene), 7.3-7.9 (multiplet, 5H, aromatic).

2,3-Diphenyl-1-azirine (100b). 2,3-Diphenyl-1-azirine (100b) was prepared in 83% overall yield from trans-stilbene, according to a published procedure.[52b] After two recrystallizations

from hexane, compound 100b melted at 66.5-70.5° (lit.[52b] 60-62°) and showed the following nmr spectrum ($CDCl_3$): δ3.29 (singlet, 1H, benzyl), 7.20 (ca. singlet, 5H, aromatic), 7.4-8.0 (multiplet, 5H, aromatic).

2-Phenyl-3-carbethoxy-1-azirine (100c). This compound was prepared by pyrolyzing 3-phenyl-5-ethoxyisoxazole (108)[53b] at 200° for 30 minutes, according to the method of Nishiwaki.[53a] 2-Phenyl-3-carbethoxy-1-azirine (100c) was isolated in 62% yield, and was kugelrohr distilled (90-100°/0.35 mm) prior to using. Its nmr spectrum (CCl_4) showed δ1.21 (triplet, J=7 Hz, 3H, $CH_2\underline{CH_3}$), 2.68 (singlet, 1H, methine), 4.12 (quartet, J=7 Hz, $\underline{CH_2}CH_3$), 7.3-7.9 (multiplet, 5H, aromatic).

Treatment of 2-Phenyl-1-azirine (100a) with Methyl Triflate (11b). An nmr sample tube fitted with a serum cap was evacuated (0.05 mm) and filled with dry nitrogen. It was then placed in a drybox, and 2-phenyl-1-azirine (100a, 0.20 ml) was added to the tube via a hypodermic syringe. Subsequent injection of two drops of neat methyl triflate (11b) resulted in an immediate, exothermic reaction, which blew the serum cap off of the sample tube. The material in the tube smoked, blackened, and collapsed to an intractable, CCl_4-insoluble tar.

In a second experiment, a 0.50 M solution of 2-phenyl-1-azirine (100a) in carbon tetrachloride (3.0 ml, 1.5 mmol) was placed in a 10-ml round-bottomed flask, equipped with a

magnetic stirrer, in a drybox. The solution was frozen with a Dry Ice-acetone bath, and onto it was layered a 0.50 M solution of methyl triflate (11b) in dichloromethane (3.0 ml, 1.5 mmol). The cold bath was removed, and the two-phase system was allowed to thaw and mix. The solution darkened upon mixing, and a black tar separated from it. The insoluble material was not investigated further.

Treatment of 2,3-Diphenyl-1-azirine (100b) with Methyl Triflate (11b). 2-H-3,4,6,7-Tetraphenyl-2,5-diaza-2,4,6-heptatrienium Triflate (109). A 200-ml round-bottomed flask equipped with a magnetic stirrer was placed in a drybox, and charged with a solution of 2,3-diphenyl-1-azirine (100b, 3.87 g, 0.020 mol) in carbon tetrachloride (40 ml). The solution was frozen with a Dry Ice-acetone bath, and to it was added over a period of ten minutes a 0.50 M solution of methyl triflate (11b) in dichloromethane (40 ml, 0.020 mole). The cold bath was removed and the solution was allowed to warm to ambient temperature, during which time it changed from yellow to red. Stirring the mixture overnight precipitated the crude 2-H-3,4,6,7-tetraphenyl-2,5-diaza-2,4,6-heptatrienium triflate (109). The brilliant yellow solid was collected by filtration in the drybox (1.28 g, 23%) and was found to melt at 145-148°. Treatment of the filtrate with ether precipitated a second crop of 109 (1.27 g, 23%),

which melted at 147-149.5°. The first crop of 109 was recrystallized three times from absolute ethanol to afford the analytical sample: mp 162-164°; NMR SPECTRUM 22 (SO_2) δ3.31 (singlet, 3H, CH_3), 6.34 (singlet, 1H, vinyl), 7.13 (singlet, 5H, aromatic), 7.29 (singlet, 5H, aromatic), 7.4-8.2 (multiplet, 10H, aromatic); mass spectrum (70eV) m/e 118, 178, 323, 399 (base), 400 (P^+ 551 unobsd).

Anal. Calcd for $C_{30}H_{25}F_3N_2O_3S$: C, 65.44; H, 4.58; N, 5.09. Found: C, 65.58; H, 4.65; N, 5.08.

The experimental conditions described above were modified to enable continuous spectroscopic observation of the reaction. Into an nmr sample tube was placed 2,3-diphenyl-1-azirine (100b, 39 mg, 0.20 mmol). The tube was covered with a serum cap and attached via a hypodermic needle to a vacuum manifold, which was equipped with a source of dry nitrogen and a reservoir of dried (with P_2O_5) liquid sulfur dioxide. The sample tube was evacuated to a pressure of 0.10 mm, purged with nitrogen, and evacuated again. The cycle was repeated four times. The tube was then immersed in a Dry Ice-acetone bath, and liquid sulfur dioxide (ca. 0.5 ml) was distilled into the solution of 100b. A 0.5 M solution of methyl triflate (11b) in carbon tetrachloride (0.40 ml, 0.20 mmol) was then injected into the sample tube, and the tetramethylsilane standard was added. The tube was sealed with a torch and removed from the cold bath. Nmr spectra were recorded at various time

intervals, beginning 30 minutes after t_o, the time at which the temperature of the sealed sample tube had reached 25°. The spectra indicated that most of the 2,3-diphenyl-1-azirine (100b) was consumed within t_o + 1 hour. After the disappearance of 100b, there were no deshielded aromatic resonances (δ7.5-8.0, indicative of PhC=N) detected until t_o + 3 hours. An unassigned singlet at δ3.82, which was present at t_o + 0.5 hour, gradually declined in intensity and disappeared within t_o + 3 hours. Another unidentified singlet (δ2.87, also present at t_o + 0.5 hour) was consumed between 10 and 27 hours after t_o. The diazatriene 109 was formed in 2-3.5 hours after t_o, but began to decompose 24 hours later to what was apparently the N-methyltetraphenylpyrazinium triflate, 111 (vide infra).

Treatment of 2-H-3,4,6,7-Tetraphenyl-2,5-diaza-2,4,6-heptatrienium Triflate (109) with Aqueous Base. 3,4,6,7-Tetraphenyl-2,5-diaza-2,4,6-heptatriene (110). Into a 100-ml round-bottomed flask equipped with a magnetic stirrer was placed 2-H-3,4,6,7-tetraphenyl-2,5-diaza-2,4,6-heptatrienium triflate (109, 0.88 g, 1.6 mmol), 5% aqueous sodium hydroxide (40 ml), and ether (40 ml). The mixture was stirred at room temperature for five minutes, after which time the layers were separated. The aqueous phase was washed with ether, and the combined ethereal layer and washes were washed successively with 5% aqueous sodium

bicarbonate, water, and saturated sodium chloride. The organic solution was then treated with anhydrous magnesium sulfate, filtered, and concentrated *in vacuo* to produce the crude free base (**110**, 0.64 g, 100%). The yellow-orange solid was recrystallized three times from absolute ethanol and dried (40°/0.10 mm) overnight, to furnish the analytical sample of 3,4,6,7-tetraphenyl-2,5-diaza-2,4,6-heptatriene, **110**: mp 157.5-159.5°; NMR SPECTRUM 23 (SO_2) δ2.98 (singlet, 3H, CH_3), 5.78 (singlet, 1H, vinyl), 6.8-8.2 (multiplet, 20H, aromatic); mass spectrum (70eV) m/e 118, 178, 324, 400, 401 (base, P^+).

Anal. Calcd for $C_{29}H_{24}N_2$: C, 86.96; H, 6.04; N, 7.00. Found: C, 86.90; H, 6.12; N, 6.92.

Treatment of 3,4,6,7-Tetraphenyl-2,5-diaza-2,4,6-heptatriene (**110**) with Trifluoromethanesulfonic Acid. 2-H-3,4,6,7-Tetraphenyl-2,5-diaza-2,4,6-heptatrienium Triflate (**109**). Into a 5-ml round-bottomed flask equipped with a magnetic stirrer was placed a solution of the free base **110** (40 mg, 0.10 mmol) in carbon tetrachloride (0.40 ml). The flask was transferred to a drybox, and trifluoromethanesulfonic acid (3M Company, *ca.* 0.02 ml) was added to the solution with stirring. Enough ether (*ca.* 10 drops) was added to effect solution, and the system was stirred overnight at ambient temperature. The resulting dark burgundy solution was concentrated *in vacuo*. Comparison of the nmr spectrum of the residue with that of authentic material (NMR SPECTRUM

23) indicated that the product was 2-H-3,4,6,7-tetraphenyl-2,5-diaza-2,4,6-heptatrienium triflate, 109.

Authentic N-Methyltetraphenylpyrazinium Triflate (111). A 0.5 M solution of methyl triflate (11b) in dichloromethane (5.0 ml, 2.5 mmol) was added to a refluxing solution of tetraphenylpyrazine (112[54], 0.77 g, 2.0 mmol) in chloroform (10 ml), in a 25-ml round-bottomed flask. The resulting orange solution was refluxed for five minutes, and then allowed to stand at room temperature for one hour. Subsequent addition of anhydrous ether (ca. 10 ml) precipitated an off-white solid, which was collected by filtration and washed with ether. The solid (0.44 g) was treated with hot ethanol, and a small amount of unreacted tetraphenylpyrazine was removed by filtration. The filtrate was concentrated in vacuo, and the residual solid was recrystallized three times from absolute ethanol. Pure N-methyltetraphenylpyrazinium triflate (111) was obtained as white needles which emitted a blue fluorescence under ultraviolet light. The compound melted at 264-266° and analyzed as follows: NMR SPECTRUM 24 (SO_2) δ3.97 (singlet, 3H, CH_3), 7.2-7.5 (multiplet, 10H, aromatic), 7.57 (singlet, 10H, aromatic); mass spectrum (70eV) m/e 178, 385, 400 (base) (P^+ 549 (unobsd).

Anal. Calcd for $C_{30}H_{23}F_3N_2O_3S$: C, 65.68; H, 4.23; N, 5.11. Found: C, 65.59; H, 4.24; N, 5.12.

Treatment of 2-H-3,4,6,7-Tetraphenyl-2,5-diaza-2,4,6-

heptatrienium Triflate (109) with Aqueous-Ethanolic Acid. N-Methyltetraphenylpyrazinium Triflate (111). A dark red solution of 2-H-3,4,6,7-tetraphenyl-2,5-diaza-2,4,6-heptatrienium triflate (109, 1.00 g, 1.82 mmol), 10% aqueous hydrochloric acid (50 ml), and 95% ethanol (50 ml) was refluxed overnight in a 200-ml round-bottomed flask. The ethanol in the resulting orange solution was removed in vacuo, and the residue was extracted with dichloromethane. The organic phase was separated and treated with saturated sodium chloride. Evaporation of the product layer at reduced pressure afforded crude N-methyltetraphenylpyrazinium triflate (111, 0.40 g, 40%) as a tan powder. The material was found to melt over a broad range (155-195°). Two recrystallizations from absolute ethanol furnished white needles which melted at 262.5-264°. This material was shown to be identical to authentic 111 by mixture melting point determination, nmr and mass spectral comparison, and behavior under ultraviolet light.

Treatment of 2-Phenyl-3-carbethoxy-1-azirine (100c) with Methyl Triflate (11b). A 1.5x15-cm test tube was placed in a drybox, charged with 2-phenyl-3-carbethoxy-1-azirine (100c, 0.38 g, 2.0 mmol) and carbon tetrachloride (4 ml), and immersed in a Dry Ice-acetone bath. To the frozen solution was added a solution of methyl triflate (11b, 0.33 g, 2.0 mmol) in dichloromethane (4 ml). The temperature

of the two-phase system was maintained at -78° for ten minutes. The cold bath was then removed, and the mixture was allowed to warm to ambient temperature. The system was stirred magnetically overnight, after which time it was shown by nmr spectroscopy that the starting materials 100c and 11b were largely unreacted. The former compound was completely consumed within one week, but its decomposition products were not identified.

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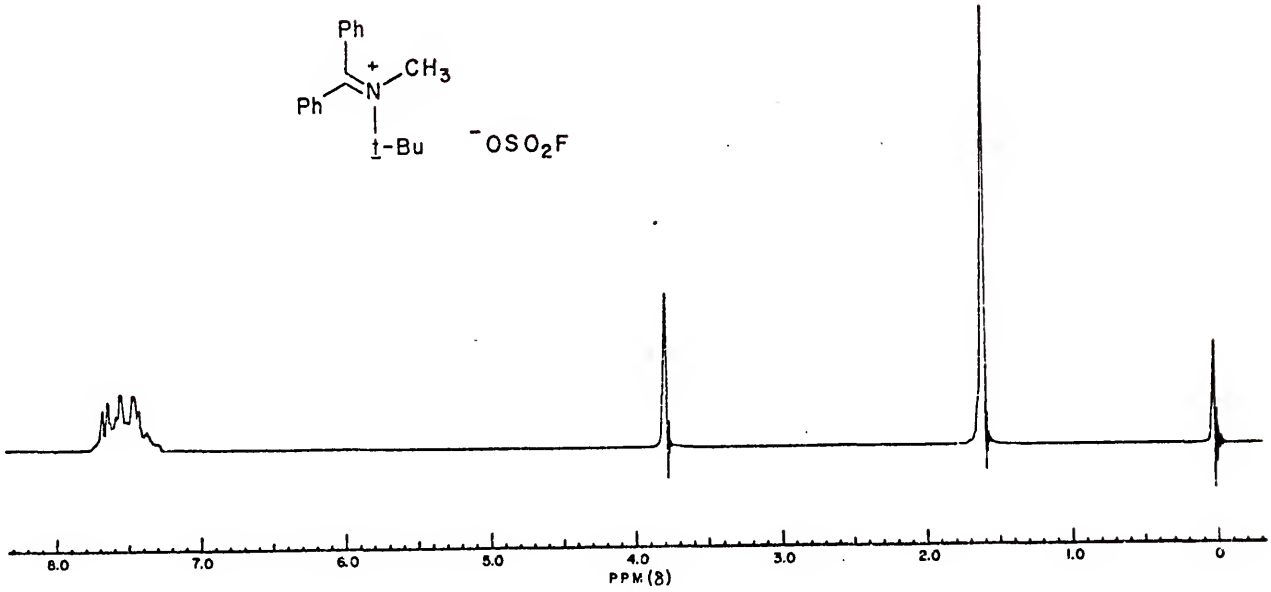
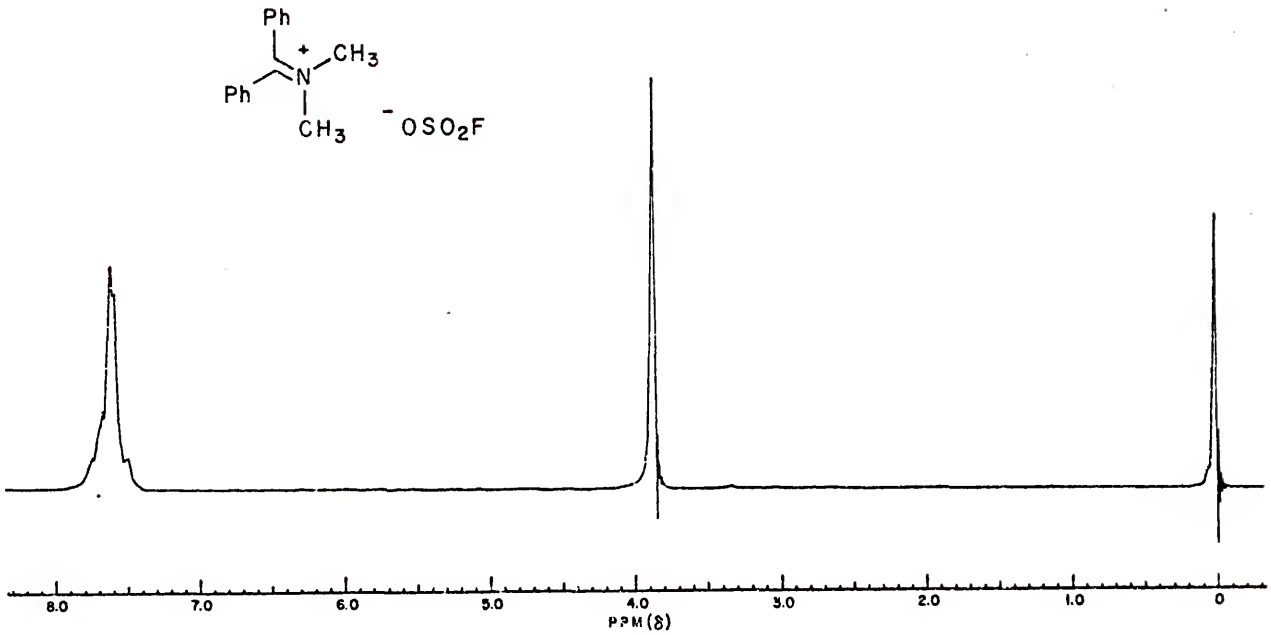
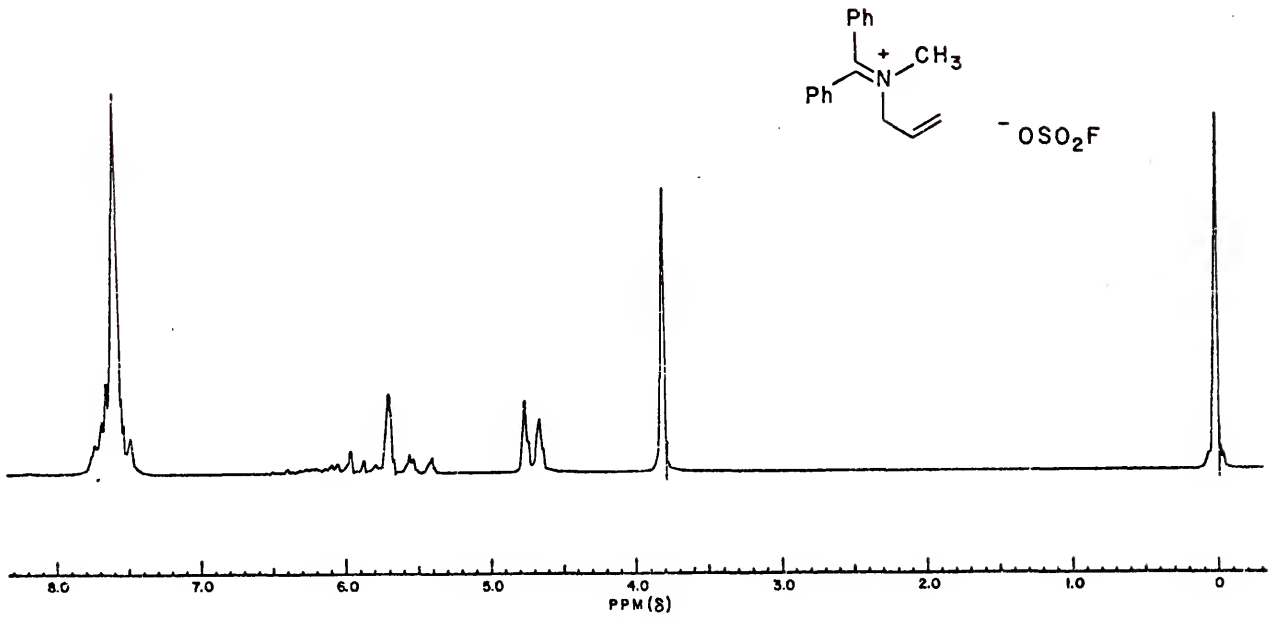
NMR SPECTRA



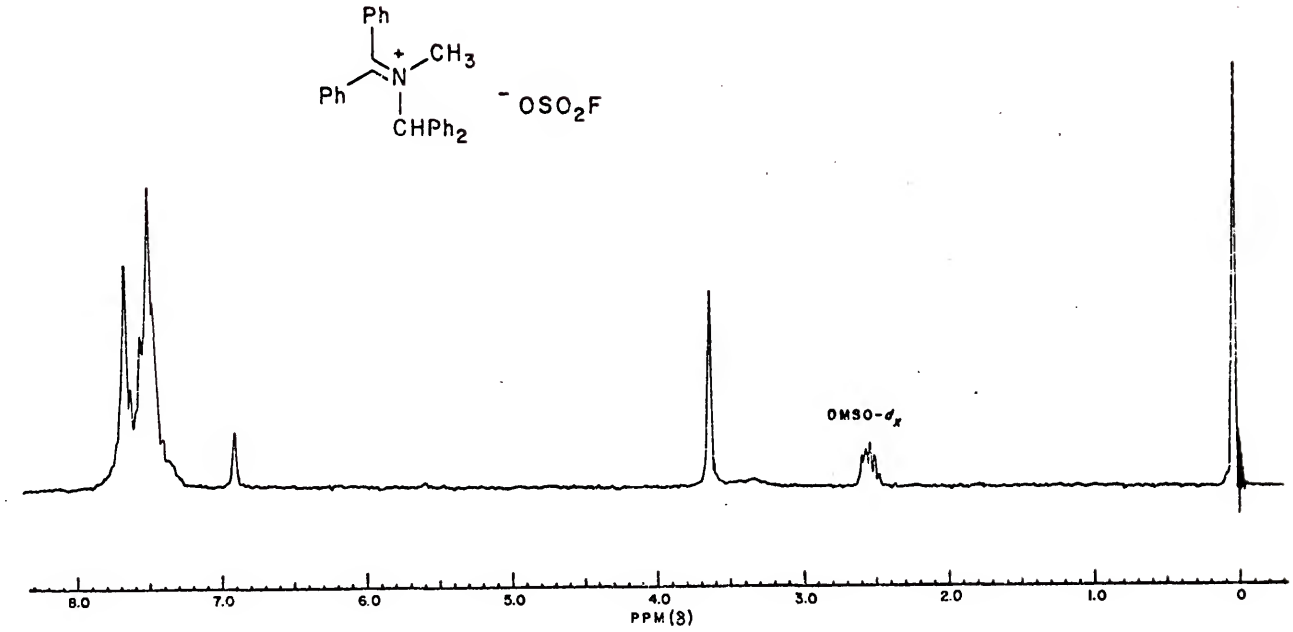
NMR SPECTRUM 1. N-(Benzhydrylidene)methyl-tert-butylaminium Fluorosulfonate (12a) in SO_2.



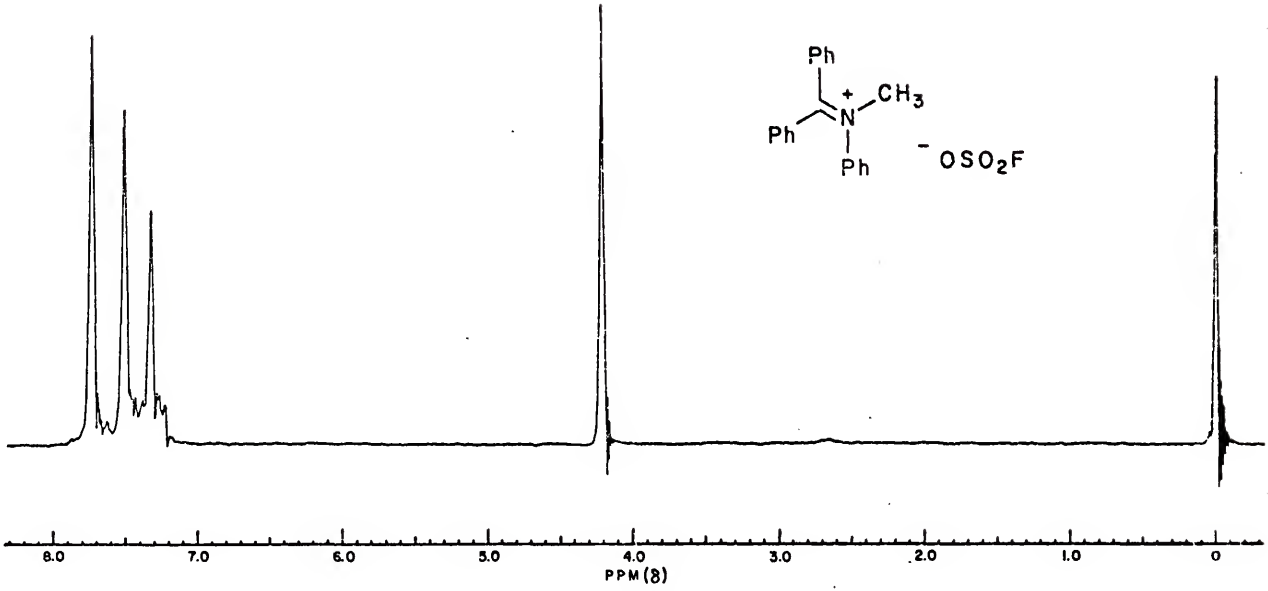
NMR SPECTRUM 2. N-(Benzhydrylidene)dimethylaminium Fluorosulfonate (12b) in SO_2.



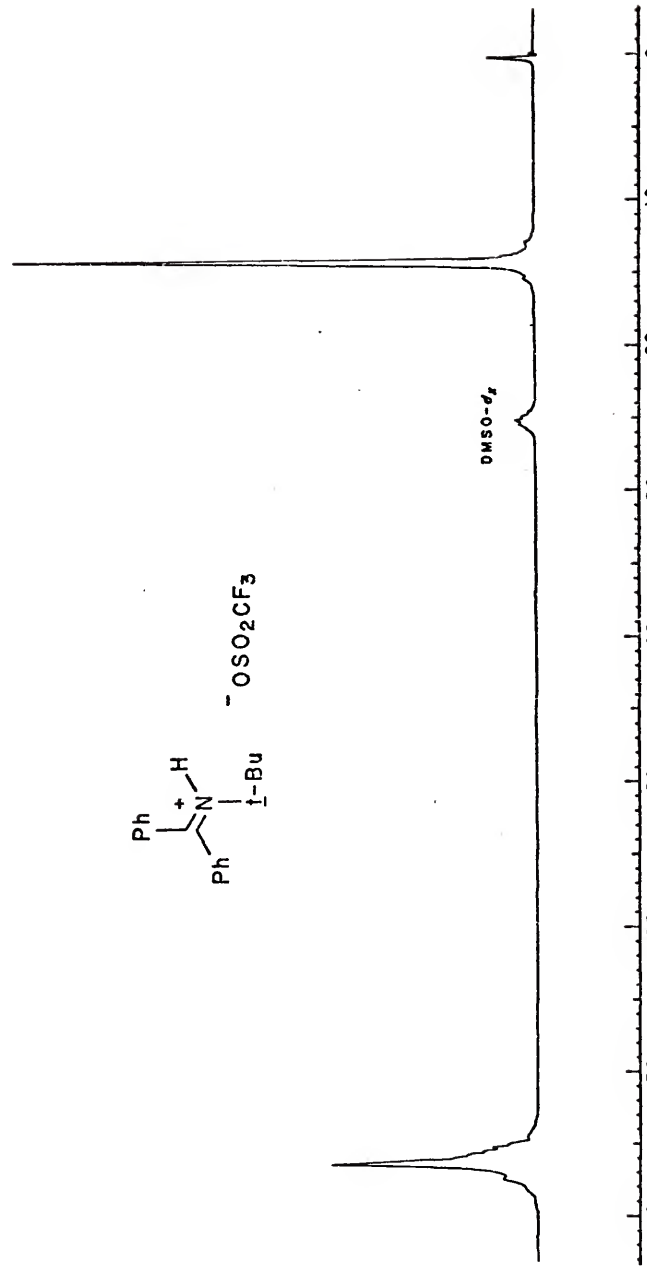
NMR SPECTRUM 3. N-(Benzhydrylidene)methylallylaminium Fluorosulfonate (12c) in SO_2.



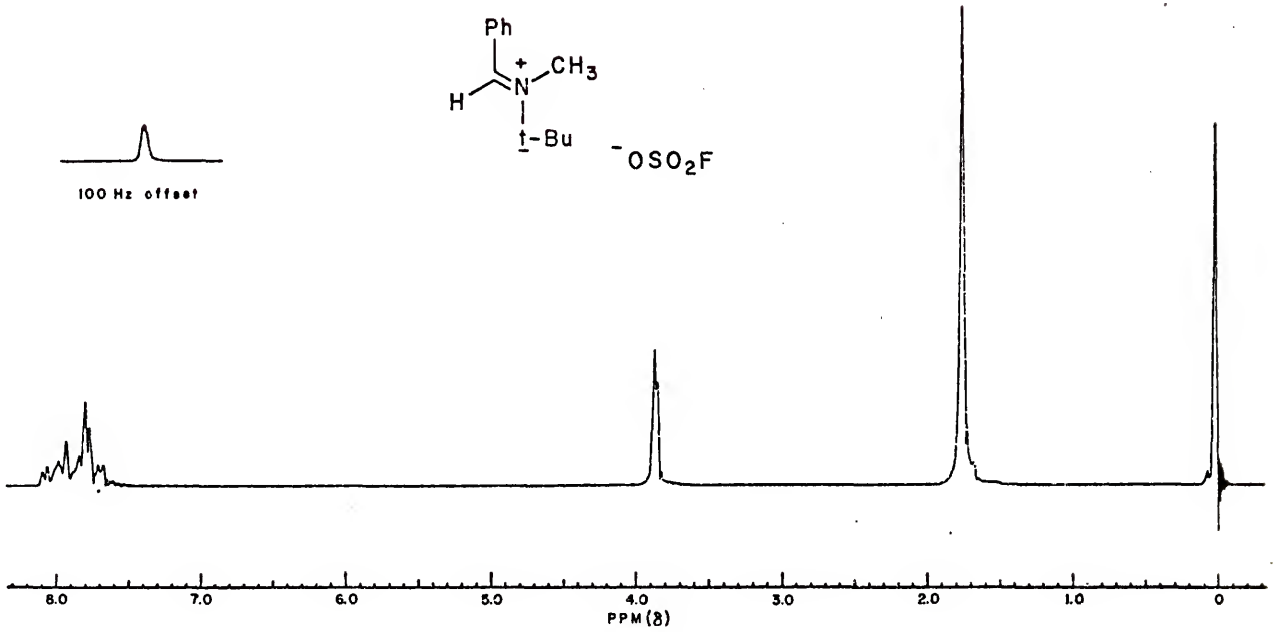
NMR SPECTRUM 4. N-(Benzhydrylidene)methylbenzhydrylaminium Fluorosulfonate (12d) in DMSO-d_6.



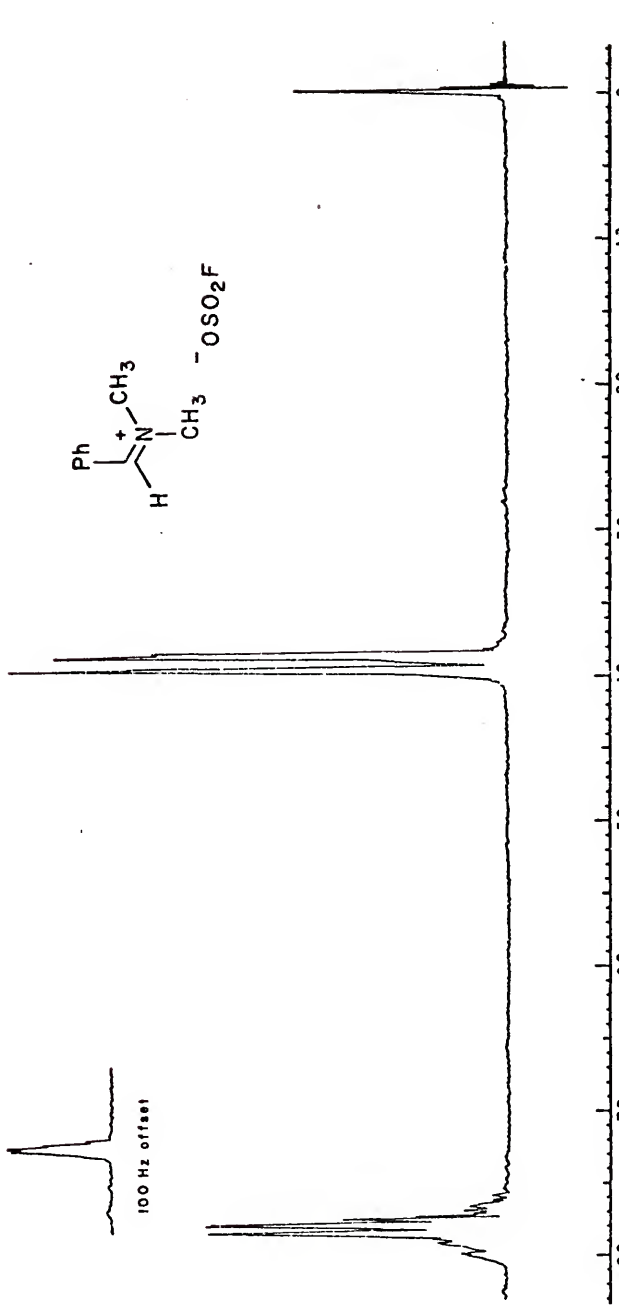
NMR SPECTRUM 5. N-(Benzhydrylidene)methylanilinium Fluorosulfonate (12e) in SO_2.



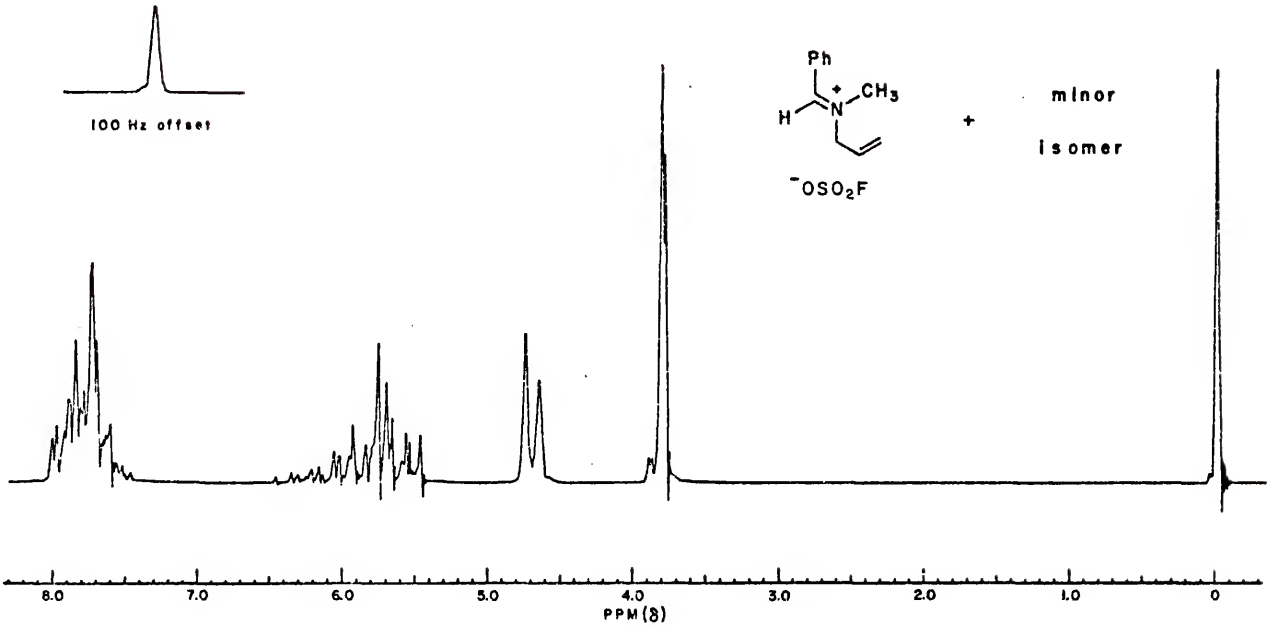
NMR SPECTRUM 6. N-(Benzhydrylidene)tert-butyliminium Triflate (20) in DMSO-d_6.



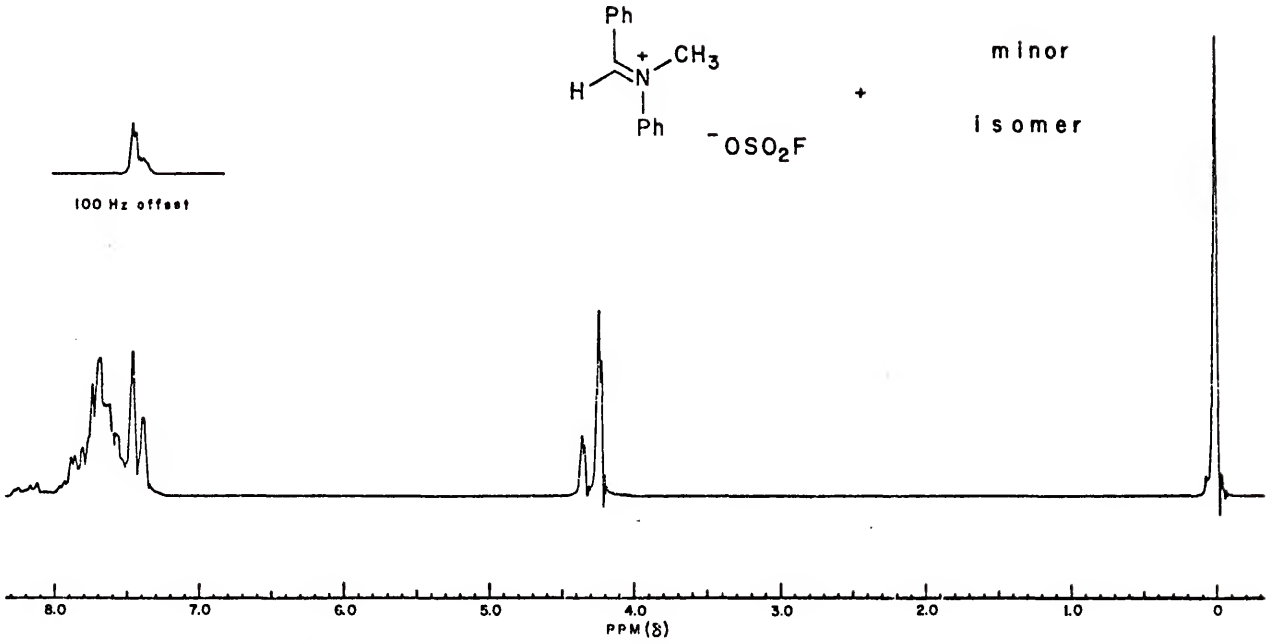
NMR SPECTRUM 7. N-(Benzylidene)methyl-tert-butylaminium Fluorosulfonate (14a) in SO_2.



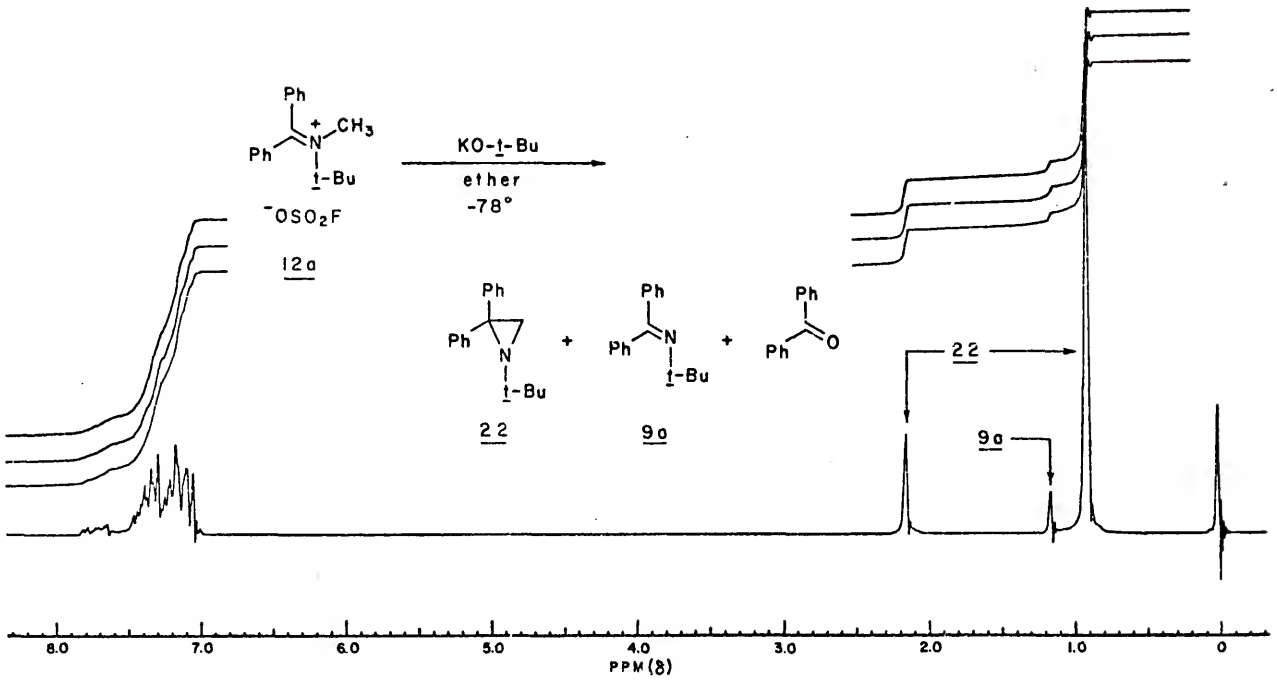
NMR SPECTRUM 8. N-(Benzylidene)dimethylaminium Fluorosulfonate (14b) in SO_2.



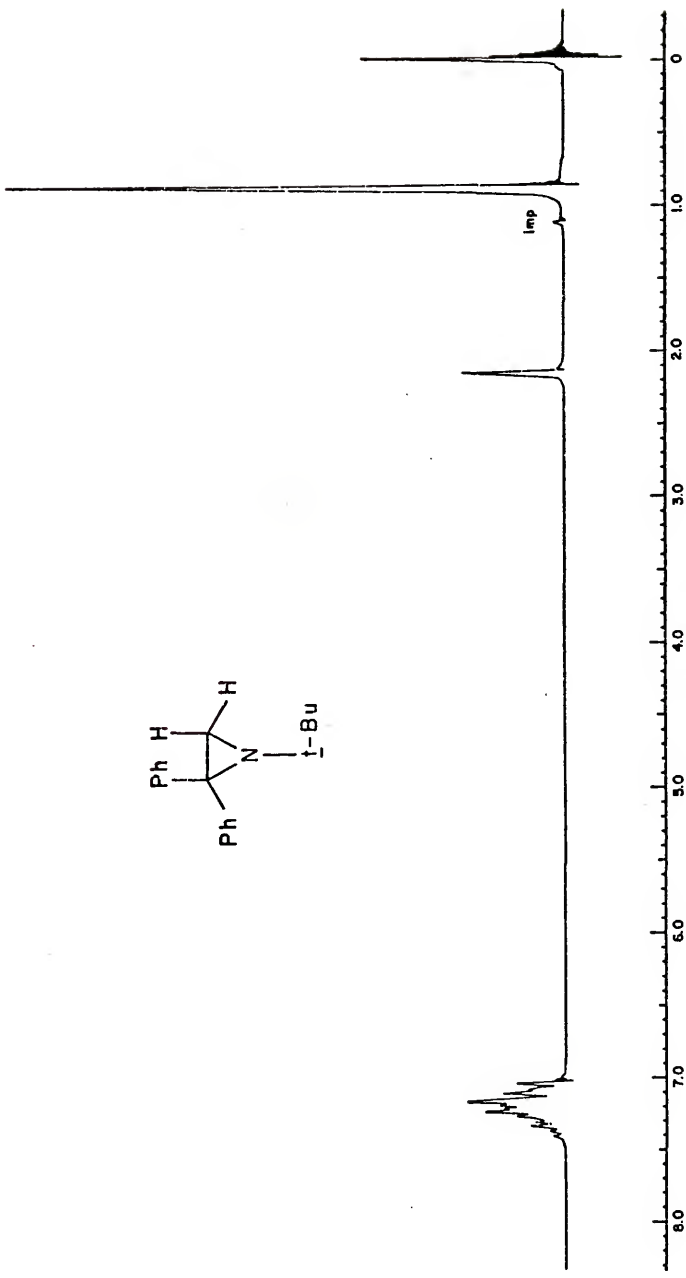
NMR SPECTRUM 9. Isomers of N-(Benzylidene)methylallylaminium Fluorosulfonate (14c) in SO_2.



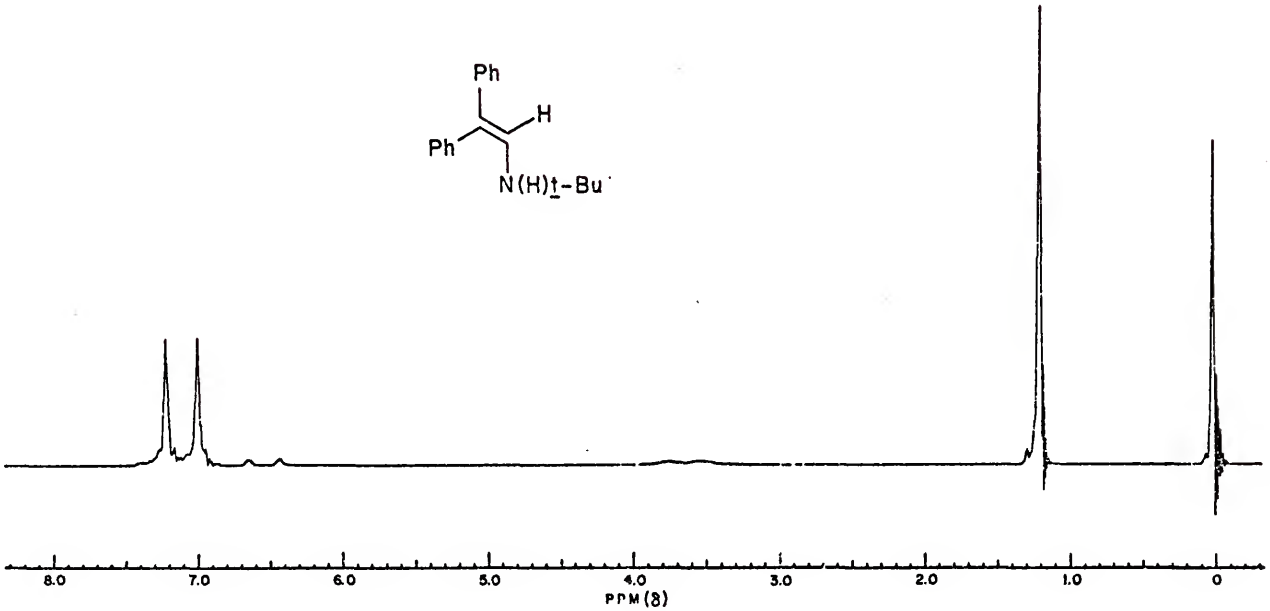
NMR SPECTRUM 10. Isomers of N-(Benzylidene)methylanilinium Fluorosulfonate (14e) in SO_2.



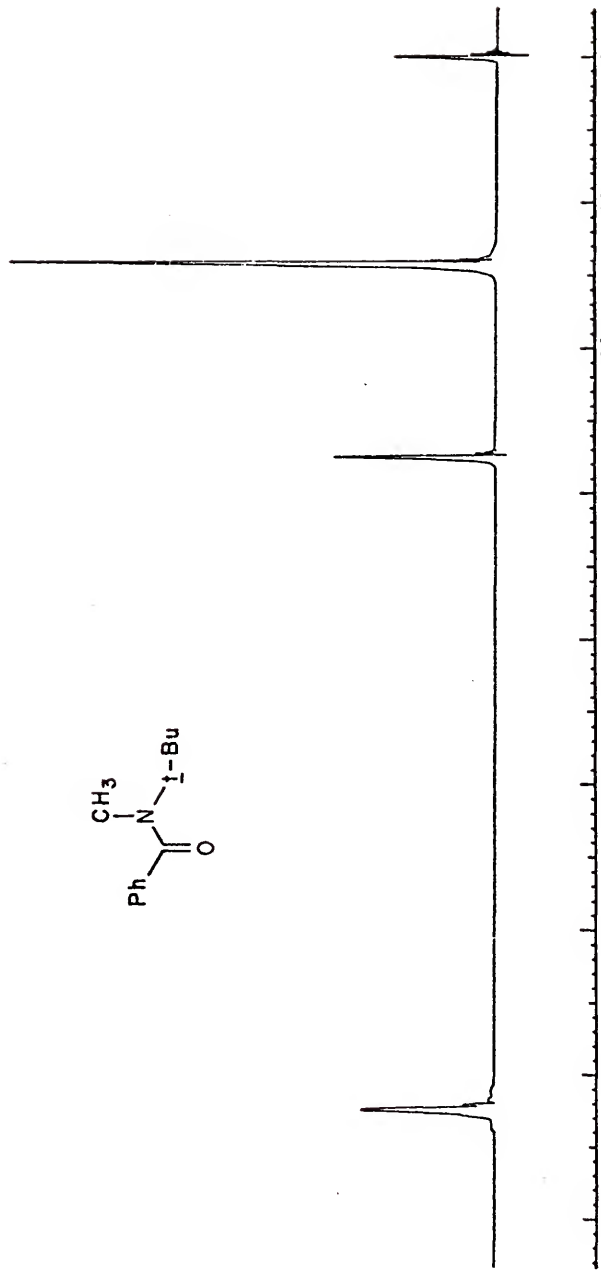
NMR SPECTRUM 11. Mixture (in CCl_4) Obtained from the Reaction of 12a with Potassium tert-Butoxide in Ether.



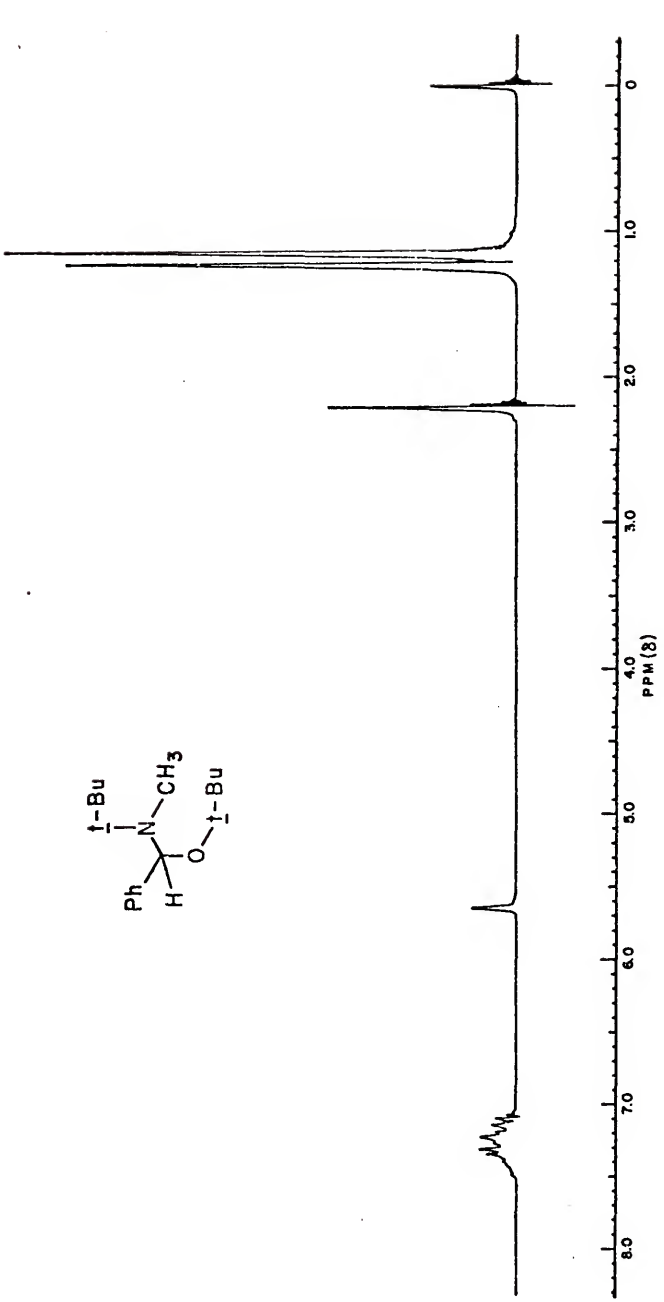
NMR SPECTRUM 12. 1-tert-Butyl-2,2-diphenylaziridine (22) in CCl_4.



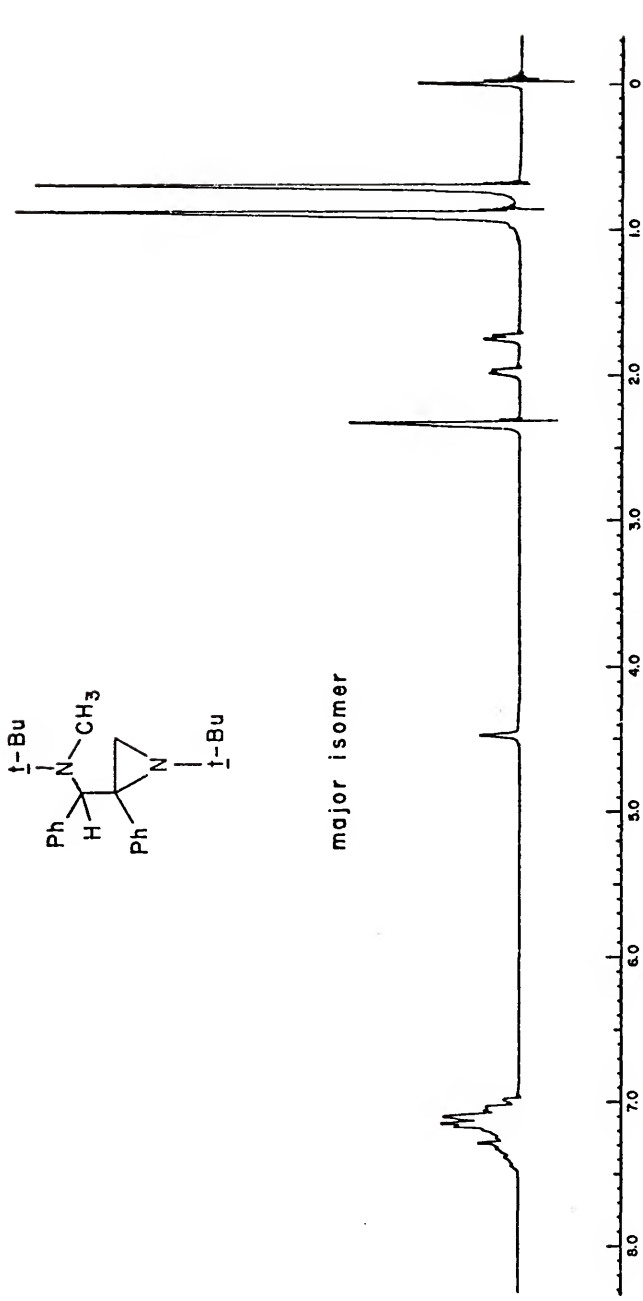
NMR SPECTRUM 13. 1-tert-Butylamino-2,2-diphenylethylene (31) in CCl_4.



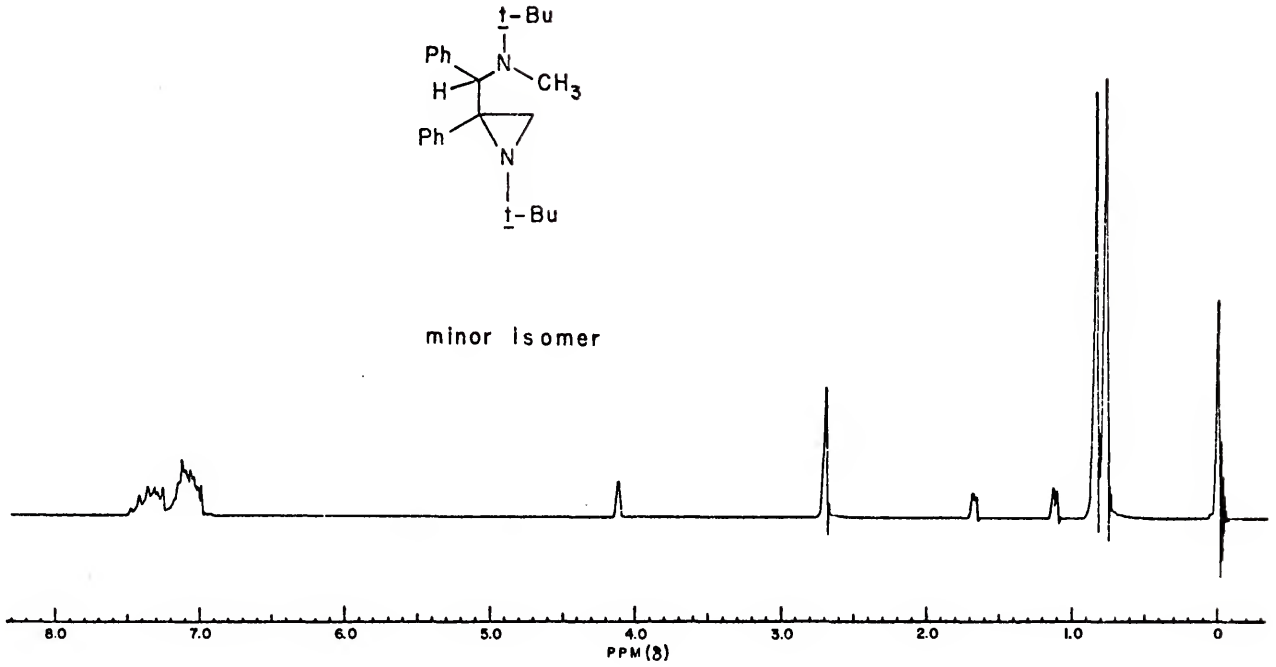
NMR SPECTRUM 14. N-Methyl-N-tert-butylbenzamide (47) in CCl_4.



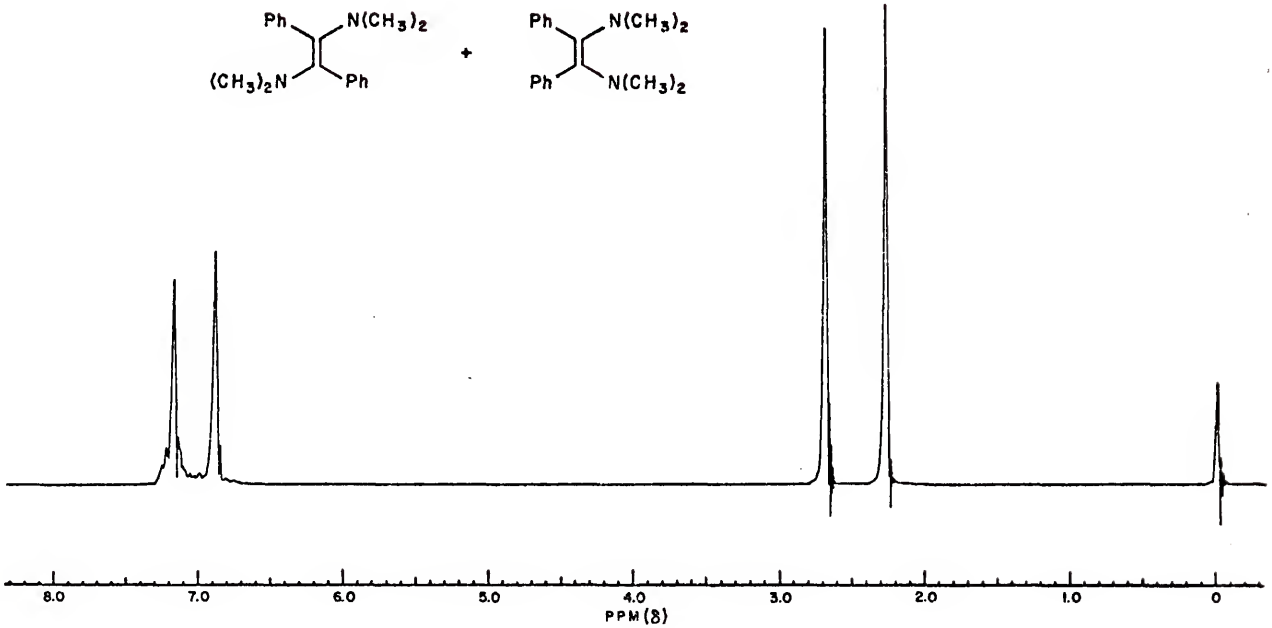
NMR SPECTRUM 15. Aminoether 48 in CCl_4.



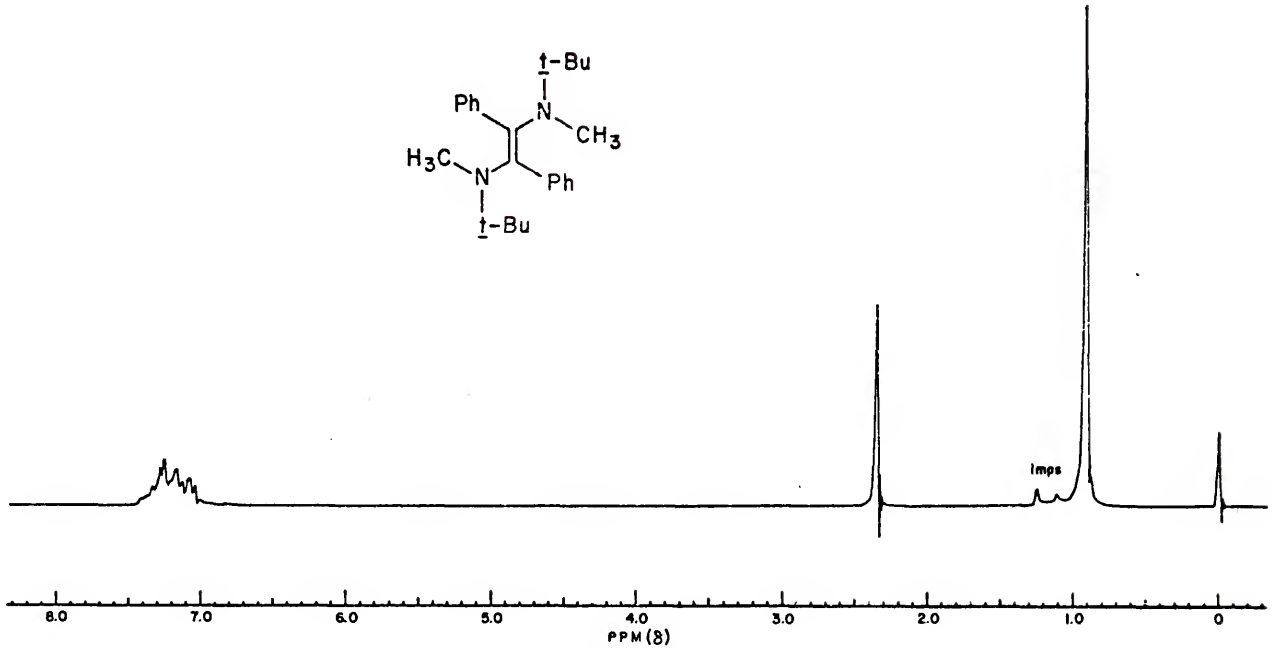
NMR SPECTRUM 16. Major Isomer of Aminomethylaziridine 50 (major-50) in CCl_4.



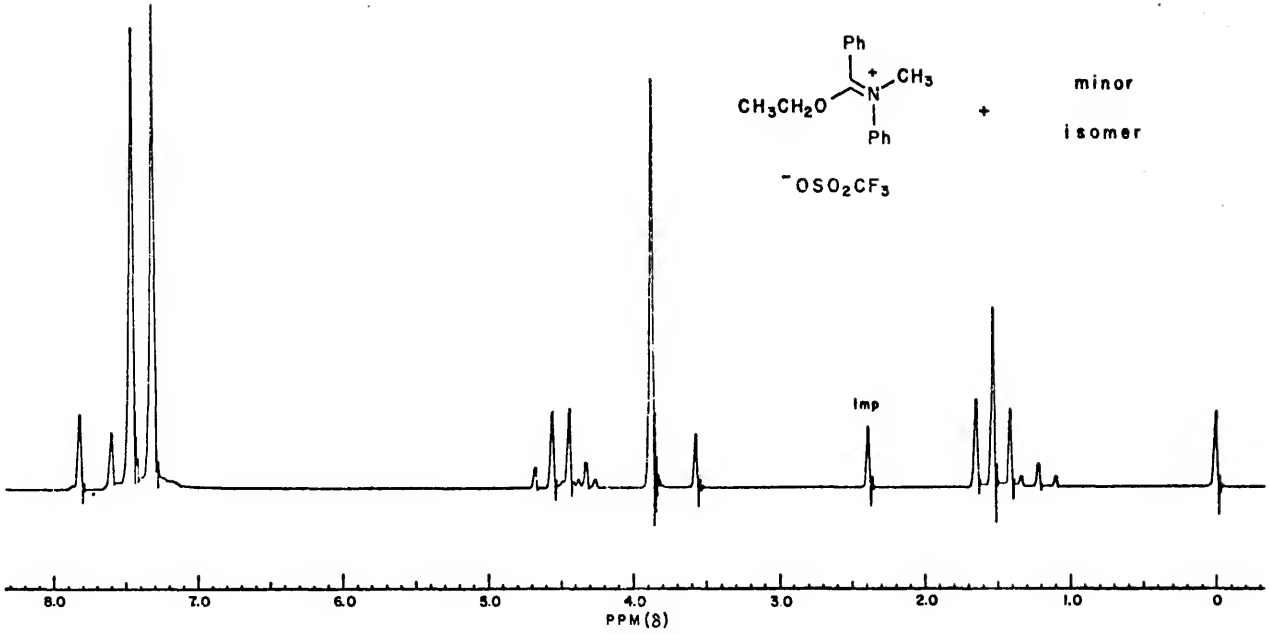
NMR SPECTRUM 17. Minor Isomer of Aminomethylaziridine 50 (minor-50) in CCl_4.



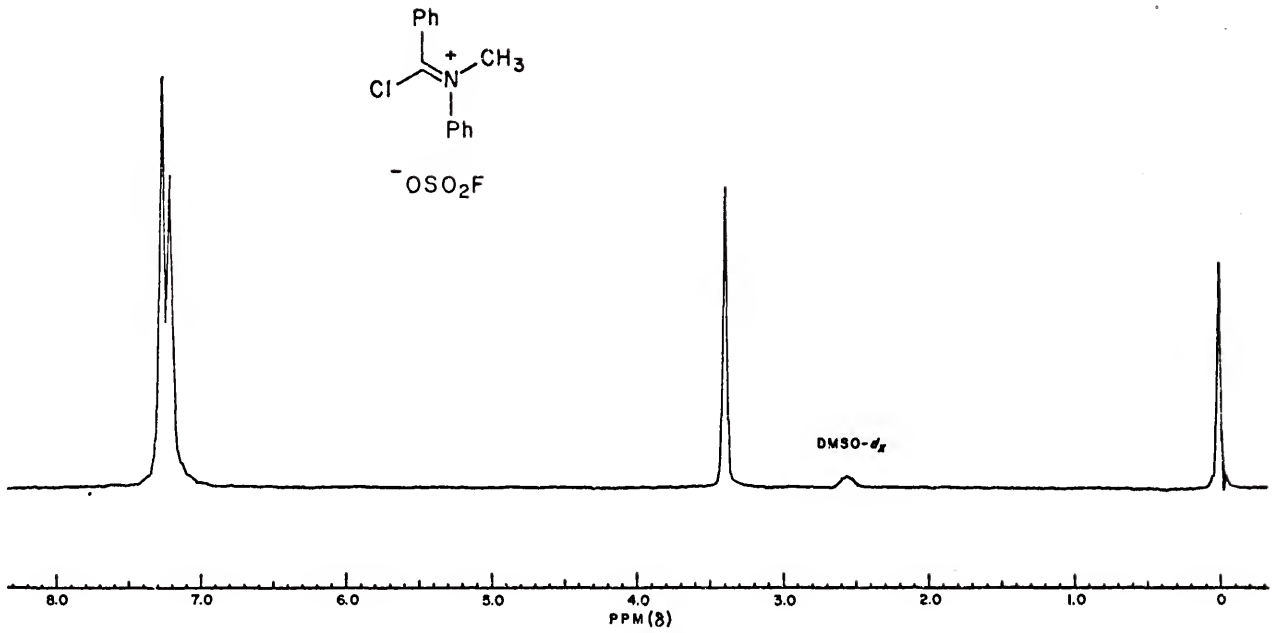
NMR SPECTRUM 18. Isomers of α,α'-Bis(dimethylamino)stilbene (53) in CCl_4.



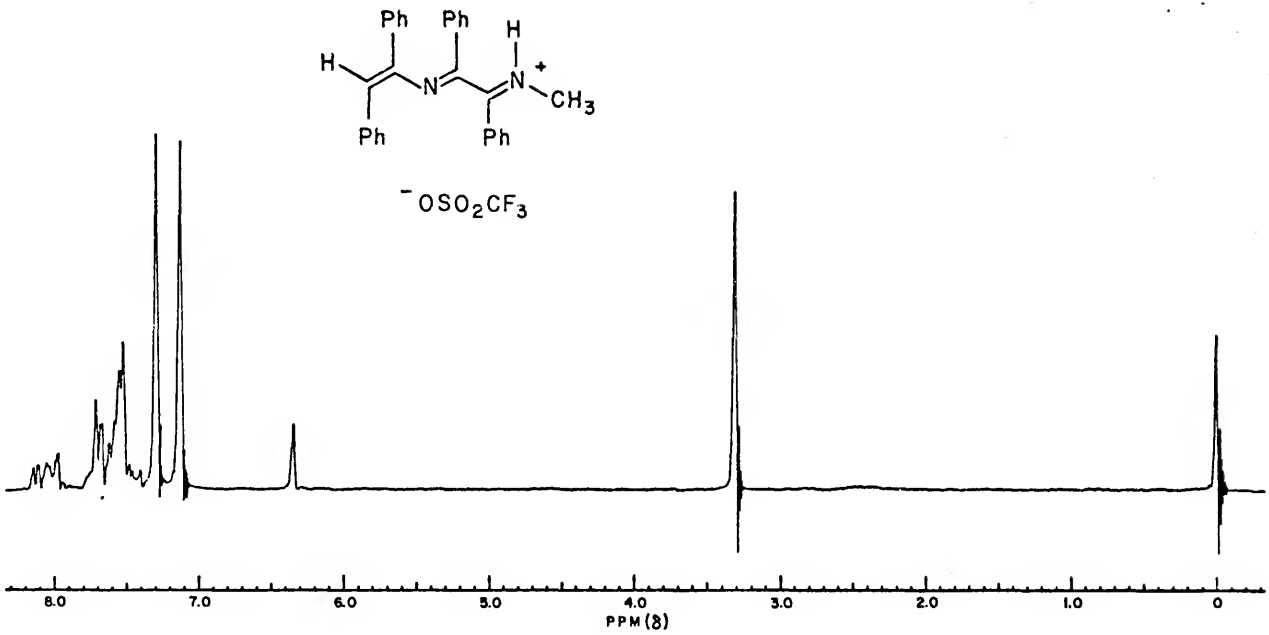
NMR SPECTRUM 19. α,α'-Bis(methyl-tert-butylamino)stilbene (52) in CCl_4.



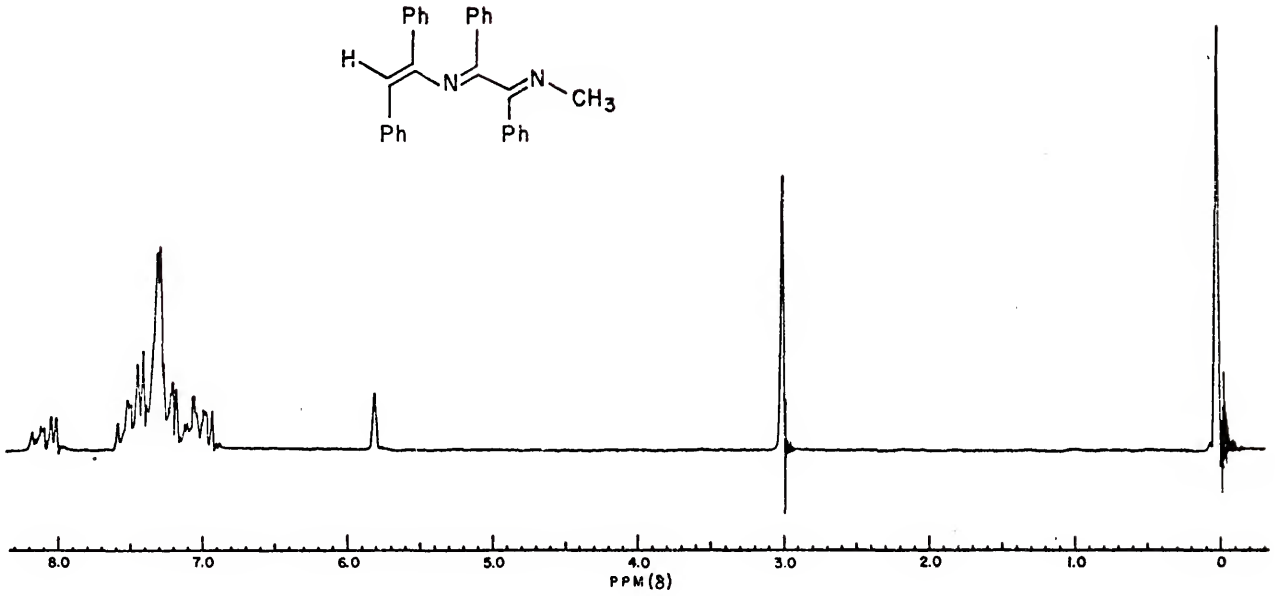
NMR SPECTRUM 20. Isomers of N-(α-Ethoxybenzylidene)methylanilinium Triflate (98) in SO_2.



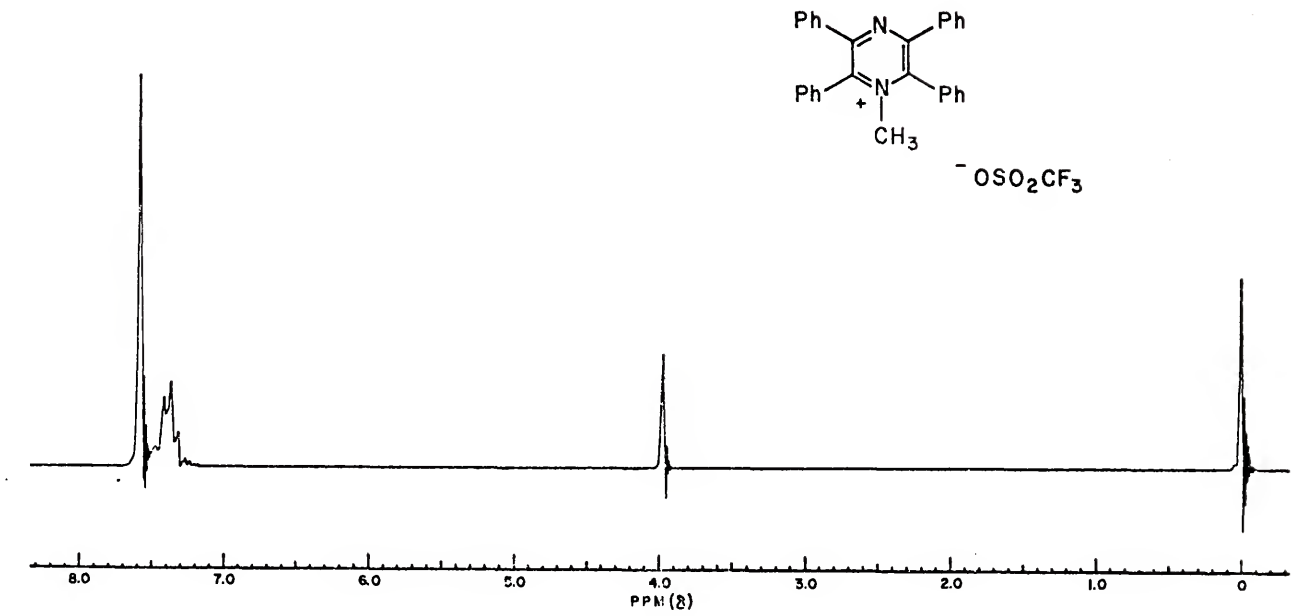
NMR SPECTRUM 21. N-(α-Chlorobenzylidene)methylanilinium Fluorosulfonate (99) in DMSO-d_6.



NMR SPECTRUM 22. 2-H-3,4,6,7-Tetraphenyl-2,5-diaza-2,4,6-heptatrienium Triflate (109) in SO_2.



NMR SPECTRUM 23. 3,4,6,7-Tetraphenyl-2,5-diaza-2,4,6-heptatriene (110) in SO_2.



NMR SPECTRUM 24. N-Methyltetraphenylpyrazinium Triflate (111) in SO_2.

BIOGRAPHICAL SKETCH

William Anthony Szabo was born on September 19, 1945, in Coronado, California. His family moved to New Jersey shortly thereafter, where he graduated from Long Branch High School in June, 1963. He received the Bachelor of Arts degree in Chemistry from Lehigh University in June, 1967, and upon graduating was employed as a pharmaceutical chemist by McNeil Laboratories, Inc. (Fort Washington, Pennsylvania).

In January, 1970, Mr. Szabo enrolled in the Graduate School of the University of Florida to pursue doctoral studies in the Department of Chemistry. He held a joint research assistantship in the Department of Physiology until August, 1971, and a teaching assistantship in the Department of Chemistry from September, 1971 to June, 1972.

William Anthony Szabo received the DuPont Award for Excellence in Teaching in 1972, and has been a member of the American Chemical Society since 1968. Upon graduation, he will begin postdoctoral study at Wesleyan University with Professor Max Tishler.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

James A. Deyrup
Professor of Chemistry

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Paul Tarrant
Professor of Chemistry

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

John F. Helling
Associate Professor of Chemistry

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Gus J. Palenik
Professor of Chemistry

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Lea G. Gramling
Professor of Pharmaceutical Chemistry

This dissertation was submitted to the Graduate Faculty of the Department of Chemistry in the College of Arts and Sciences and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

December, 1974

Dean, Graduate School