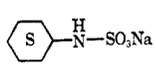
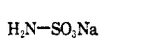
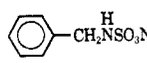
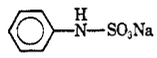
The mechanism of hydrolysis of sulfamic acid proposed by previous workers[5,6] involves rate-determining cleavage of the N–S bond without participation of water (A-1 mechanism). Hydrolysis of the N-substituted sulfamates in aqueous acid by a similar mechanism would then be analogous to the established mechanism[4] for hydrolysis of substituted sulfates and thiosulfates (I and II). On this basis, one might predict that since nitrogen and oxygen are both in period II of the periodic table the reactivity pattern of the sulfamates would more closely resemble that of compounds of type II than type I. This is borne out in the results presented in Table I. The 3100-fold acceleration of sodium N-phenylsulfamate compared with its saturated analog, sodium N-cyclohexylsulfamate, implies a substantial delocalization increase in the transition state for hydrolysis of the former. This is also reflected in the lower (5–6 kcal/mol) activation energy of the aryl sulfamate compared to the alkyl derivatives. The rate acceleration of the sulfamates might be compared with the 500-fold acceleration of $C_6H_5OSO_3^-Na^+$ relative to $CH_3OSO_3^-Na^+$ reported by Kice.[4]

$$\overset{+}{H} + H_2NSO_3^- \rightleftharpoons H_3\overset{+}{N}-SO_3^- \xrightarrow{\text{slow}}$$

$$NH_3 + SO_3 \xrightarrow[\text{fast}]{H_2O,} \overset{+}{N}H_4 + HSO_4^-$$

TABLE I

HYDROLYSIS RATES OF SODIUM N-SUBSTITUTED SULFAMATES IN AQUEOUS PERCHLORIC ACID

Structure	Temp, °C	k, sec^{-1}	k (rel) 99.96°	E_a, kcal/mol
	89.98	7.44×10^{-6}		
	99.96	2.56×10^{-5}		
	109.75	7.53×10^{-5}	1	32.4
	69.85	9.25×10^{-6}		
	80.01	3.42×10^{-5}		
	89.98	1.20×10^{-4}	13[a]	31.5
	80.01	1.24×10^{-5}		
	89.98	4.56×10^{-5}		
	99.96	1.20×10^{-4}	5	30.8
	30.61	2.65×10^{-5}		
	39.23	8.22×10^{-5}		
	48.97	2.94×10^{-4}	3100[a]	25.8

[a] From extrapolated rate data.

The relative reactivity of sodium sulfamate and the sodium N-alkylsulfamates appears to be in the order expected on the basis of inductive stabilization of the N–S bond. Indeed, the σ^* values[7] for these substituents are linearly related to the corresponding log k value ($\rho^* = 3.5$), although any argument based on those several values is obviously tenuous.

Experimental Section

Sodium sulfamate was prepared by NaOH neutralization of recrystallized sulfamic acid.

Sodium N-cyclohexylsulfamate (Abbott, Food Grade) was recrystallized first from dilute aqueous NaOH, then from ethanol–water.

Sodium N-benzylsulfamate and sodium N-phenylsulfamate were prepared by the method of Audrieth and Sveda[8] from the corresponding amines and chlorosulfonic acid. The preparation of sodium N-benzylsulfamate is presented below as an example.

Sodium N-Benzylsulfamate.—To 65.5 ml (0.6 mol) of benzylamine (Eastman, Practical Grade) dissolved in 250 ml of chloroform was added 13.2 ml (0.2 mol) of chlorosulfonic acid (Eastman, Practical) with stirring over a period of 1.5 hr at 0°. The resulting suspension of white solid was suction filtered and the insoluble material dissolved in 20 g (0.5 mol) of sodium hydroxide in 100 ml of water. After evaporation, the resulting sodium N-benzylsulfamate was thrice recrystallized from 75% ethanol to yield 6.50 g of pure material.

Anal. Calcd for $C_7H_8NSO_3Na$: S, 15.33. Found: S, 15.21.

Kinetic Procedures.—All kinetic runs were made in duplicate with solutions of 0.02 M sulfamate in 1.41 M perchloric acid which was prepared by dilution of 60% perchloric acid (J. T. Baker, Reagent Grade). The reactions were followed by titration of sulfate in aliquots of the reaction mixture using the titrimetric method of Archer.[9] All runs were made using the usual sealed ampoule technique except those on sodium N-phenylsulfamate which were conducted in a volumetric flask from which aliquots were removed. All were thermostated to ±0.05° using an oil bath in conjunction with a Sargent Thermonitor temperature control system.

Registry No.—Perchloric acid, 7601-90-3; sodium N-cyclohexylsulfamate, 139-05-9; sodium sulfamate, 13845-18-6; sodium N-benzylsulfamate, 15790-83-7; sodium N-phenylsulfamate, 15790-84-8.

Acknowledgments.—The authors thank Dr. C. G. Venier for helpful discussions and R. Jay Murray for least-squares treatment of the kinetic data. They also express appreciation to the Royal Crown Cola Co., Columbus, Ga., for their generous contribution of several starting materials.

(5) J. P. Candlin and R. G. Wilkens, *J. Chem. Soc.*, 4236 (1960).
(6) B. E. Fleischfresser and I. Lauder, *Aust. J. Chem.*, **15**, 242 (1962).
(7) J. Hine, "Physical Organic Chemistry," 2nd ed, McGraw-Hill Book Co. New York, N. Y., 1962, p 87.
(8) L. F. Audrieth and M. Sveda, *J. Org. Chem.*, **9**, 89 (1944).
(9) E. E. Archer, *Analyst*, **82**, 208 (1957).

Dihydroacridizinium Salts[1]

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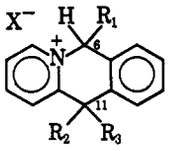
Reduction of acridizinium compounds both catalytically[2,3] and by means of sodium borohydride[3] has been previously described. In both cases reduction occurred in the quinolizinium portion of the molecule to produce benzoquinolizidines. It appeared to be of interest to study reduction under different conditions to determine whether a product could be obtained in which reduction was less complete. When a 10% Pd–C catalyst was substituted for the platinum oxide[2,3] previously employed, absorption of hydrogen at atmospheric pressure by acridizinium bromide decreased sharply after the consumption of 1 molar equiv. The colorless product which showed no significant ultraviolet absorption above 262 mμ was assigned the structure of 6,11-dihydroacridizinium (1) bromide. Acridizinium salts with substituents at the 6 and 11

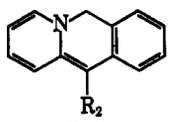
(1) This research was supported by a grant (CA-05509) from the National Cancer Institute of the National Institutes of Health.
(2) C. K. Bradsher and L. E. Beavers, *J. Amer. Chem. Soc.*, **77**, 4812 (1955).
(3) C. K. Bradsher and N. L. Yarrington, *J. Org. Chem.*, **25**, 294 (1960).

TABLE I

NMR DATA FOR 6,11-DIHYDROACRIDIZINIUM SALTS (1–7) AND ACRIDIZINES (8–9)



1–7

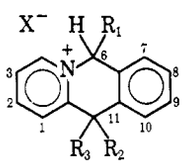


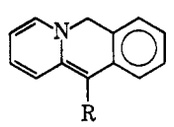
8–9

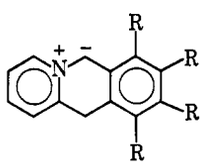
Compd	R_1	R_2	R_3	Solvent	Chemical shifts, (δ multiplicity and area) 6	11	Other nonaromatic
					Salts		
1	Me	H	H	D_2O	6.02 (s, two)	4.77 (s, two)	
2	H	H	Me	D_2O	6.02 (q, two)	4.72 (q, one)	1.93 (d, three)
3	Me	H	H	TFA[a]	6.04 (q, one)	4.60 (s, two)	1.86 (d, three)
5	H	H	$PhCH_2$	TFA	5.17 (q, two)	4.92 (t, one)	3.28 (d, two)
6	H	Me	$PhCH_2$	TFA	5.11 (q, two)		2.13 (s, three), 3.19 (s, two)
7	H	Me	Me	TFA	5.90 (s, two)		1.88 (s, six)
					Acridizines		
8		H		C[b]	5.20 (s, two)	c	
9		CH_3		C	5.05 (s, two)		2.43 (s, three)

[a] Trifluoroacetic acid. [b] Deuteriochloroform. [c] The proton at C-11 gives a signal indistinguishable from that of aromatic protons.

positions[4,5] were subjected to reduction over a palladium catalyst and likewise afforded 6,11-dihydro derivatives (2–5).







1, $R_1 = R_2 = R_3 = H$
2, $R_2 = R_2 = H$; $R_3 = Me$
3, $R_1 = Me$; $R_2 = R_3 = H$
4, $R_1 = R_2 = H$; $R_3 = Ph$
5, $R_1 = R_2 = H$; $R_3 = PhCH_2$
6, $R_1 = H$; $R_2 = Me$; $R_3 = PhCH_2$
7, $R_1 = H$; $R_2 = R_3 = Me$

8, R = H (not isolated)
9, R = CH_3

10, R = H
11, R = Cl

The nmr spectrum of 6,11-dihydroacridizinium (1) bromide in deuterium oxide showed two-proton singlets at δ 6.02, and 4.77, assigned to the methylene protons at the 6 and 11 positions, respectively. One would expect that it would be the methylene group adjacent to the positive charge on nitrogen which would be the more strongly deshielded, and examination of the nmr spectra of the 6-methyl- and 11-methyl-6,11-dihydroacridizinium salts (3 and 2, respectively) confirms this hypothesis (Table I).

Of the two types of methylene protons present in the dihydro compound (1) the *less* deshielded undergoes deuterium–hydrogen exchange more rapidly. When the salt 1 stands in neutral deuterium oxide nmr shows that 50% of the C-11 hydrogens have exchanged after 11 days while no exchange of the C-6 protons is perceptible during this period.

Since 1 resembles a 2-picolinium salt, several attempts were made to condense it with benzaldehyde in the presence of base (piperidine)[6] and acetic anhydride,[7] and under neutral conditions (sealed tube). No condensation product could be isolated, however.

An aqueous solution of **1**, on treatment with aqueous sodium hydroxide, immediately yielded a bright red precipitate. No solvent was found for the recrystallization of the precipitate, and further reactions were carried out on material that was simply washed with water. The action of base on 11-methyl-6,11-dihydroacridizinium (2) bromide afforded a purple compound with the composition to be expected if the salt had lost the elements of hydrogen bromide. The choice between the 6H-acridizine structure **8** and that of the betaine (**10**) can be made on the basis of nmr (Table I). It is quite clear from a comparison of the spectra of the two bases that the methylene group at C_6 is intact, hence the possibility of the betaine structure (**10**) can be eliminated. The tetrachlorobetaine **11** has been proposed[8] as the product of the reaction of sodium methoxide with 3,4,5,6-tetrachloro-*o*-xylylene-α,α′-dipyridinium dibromide. On the basis of our evidence the correct structure would be 7,8,9,10-tetrachloro-6H-acridizine, analogous to **8**. Addition of acid to acridizine afforded the expected dihydroacridizinium salt (**1**).

Since structure **8** is that of an anhydro base, the possibility that it might undergo alkylation reactions[9] was investigated. Addition of the red compound (**8**) to excess benzyl bromide yielded a tarry substance, which on treatment with perchloric acid yielded a crystalline product. The nmr spectrum (Table I) indicated that benzylation took place at the 11 position to give 11-benzyl-6,11-dihydroacridizinium (**5**) perchlorate. An independent preparation of **5** by reduction of 11-benzylacridizinium perchlorate (prepared by a standard method for preparation of acridizinium salts)[4b] confirmed the structure of the benzylation product.

(4) (a) C. K. Bradsher and T. W. G. Solomons, *J. Amer. Chem. Soc.*, **81**, 2550 (1959); (b) C. K. Bradsher and J. C. Parham, *J. Org. Chem.*, **28**, 83 (1963).

(5) C. K. Bradsher and J. C. Parham, *J. Heterocycl. Chem.*, **1**, 121 (1964).

(6) (a) W. H. Mills and W. J. Pope, *J. Chem. Soc.*, **121**, 946 (1922); (b) A. P. Phillips, *J. Org. Chem.*, **12**, 333 (1947).

(7) G. M. Bennett and W. L. C. Pratt, *J. Chem. Soc.*, **1929**, 1465.

(8) W. E. Rosen, *J. Org. Chem.*, **26**, 5190 (1961).

(9) (a) O. Mumm, *Ann.*, **443**, 272 (1925); (b) W. H. Mills and R. Raper, *J. Chem. Soc.*, **127**, 2466 (1925); (c) E. E. P. Hamilton and R. Robinson, *ibid.*, **109**, 1029 (1916); (d) R. Robinson and J. E. Saxton, *ibid.*, 976 (1952); (e) J. W. Armit and R. Robinson, *ibid.*, **121**, 827 (1922); (f) D. O. Holland and J. H. C. Naylor, *ibid.*, 1657 (1955).

TABLE II

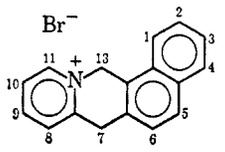
6,11-DIHYDROACRIDIZINIUM SALTS BY CATALYTIC REDUCTION

Compd	R_1	R_2	R_3	X	Yield,[a] %	Mp, °C	λ_{max},[b] mμ (log ε)	Formula	Calcd, % C	Calcd, % H	Calcd, % N	Found, % C	Found, % H	Found, % N
1	H	H	H	Br[c]	57	188.5–192	262 (3.71)	$C_{13}H_{12}BrN$	59.56	4.61	5.34	59.42	4.56	5.37
	H	H	H	ClO_4[d]		218–223		$C_{13}H_{12}ClNO_4$	55.43	4.29	4.97	55.43	4.30	4.92
2	H	H	CH_3	Br[c]	53	205–210		$C_{14}H_{14}BrN$	60.88	5.11	5.07	60.75	5.19	4.81
	H	H	CH_3	ClO_4[e]		177–179	264 (3.79)	$C_{14}H_{14}ClNO_4$	56.86	4.77	4.74	56.74	4.74	4.59
3	CH_3	H	H	ClO_4[e,f]	27	148–154	265 (3.75)	$C_{14}H_{14}ClNO_4$	56.86	4.77	4.74	56.90	4.88	4.87
4	H	H	C_6H_5	Br[g]	49	192–197		$C_{19}H_{16}BrN \cdot {}^1/_4H_2O$	66.58	4.85	4.08	66.55	4.81	3.87
	H	H	C_6H_5	ClO_4[h]		163–165	267 (3.78)	$C_{19}H_{16}ClNO_4$	63.78	4.51	3.92	63.88	4.62	3.92
5	H	H	$C_6H_5CH_2$	Br[g,i]		123.5–127		$C_{20}H_{18}BrN \cdot H_2O$	64.87	5.44	3.78	64.79	5.40	3.70
	H	H	$C_6H_5CH_2$	ClO_4[h]	7	165–167	267 (3.78)	$C_{20}H_{18}ClNO_4$	64.60	4.88	3.77	64.40	4.88	3.93

[a] Obtained by reduction of the corresponding acridizinium compound. [b] Determined in 95% ethanol. [c] Recrystallized from methanol–ethyl acetate. [d] Recrystallized from methanol. [e] Recrystallized from water. [f] Reduction carried out on bromide, but product isolated as perchlorate. [g] Recrystallized from absolute ethanol–ethyl acetate. [h] Recrystallized from absolute ethanol. [i] Obtained from the perchlorate by ion exchange.

Benzylation of 11-methyl-6H-acridizine (**9**) occurs more readily (50% yield) than it does for parent compound **8**, and likewise occurs at position 11 affording **6**. Methylation of **9** yielding **7** has likewise been accomplished. Methylation of the parent acridizine (**8**) appeared to give an inseparable mixture.

The selective reduction was extended to benz[*h*]-acridizinium bromide[10] which absorbed 1 mol of



12

hydrogen to afford what uv and nmr evidence indicate to be the 7,13-dihydro derivative (**12**).

Experimental Section

Analyses were carried out by Janssen Pharmaceutica, Beerse, Belgium, except as noted. The melting points were determined in capillary tubes using the Laboratory Devices Mel-Temp apparatus and are uncorrected. The ultraviolet absorption spectra were measured in 95% ethanol using a Beckman Model DB spectrophotometer. Nuclear magnetic resonance spectra were determined on a Varian Model A-60 nmr spectrophotometer using tetramethylsilane as a standard. Infrared spectra were obtained on a Perkin-Elmer 137 Infracord spectrophotometer using potassium bromide pellets.

Hydrogenation of Acridizinium Salts. 6,11-Dihydroacridizinium (1) Bromide.—To a suspension of 9.75 g of acridizinium bromide in 75 ml of 95% ethanol, was added 2.5 g of 10% palladium on charcoal. Themi xture was stirred under 1 atm of hydrogen. After *ca.* 20 min, 975 ml (theoretical, 925 ml) of hydrogen had been absorbed and the rate of hydrogen absorption decreased sharply. The solution was filtered and concentrated and the residual oil crystallized by addition of acetone. Recrystallization from methanol–ethyl acetate afforded 5.60 g (57%) of colorless hygroscopic crystals, mp 187–192°. The results of this and related experiments are summarized in Table II. In some of the reduction experiments there was no noticeable change in rate of hydrogenation and the experiment was simply discontinued after slightly more than 1 molar equiv had been absorbed.

11-Benzyl-6,11-dihydroacridizinium (5) Perchlorate by Alkylation.—To a solution of 2 g of 6,11-dihydroacridizinium bromide in 40 ml of water, 8 ml of 5% sodium hydroxide was added. The red precipitate which formed was collected, washed with large amounts of water, and allowed to remain on the reaction filter (with air passing through) until dry to yield 1.30 g (94%). The crude acridizine did not have a melting point, but darkened above 60°, and turned from red to yellow-brown simply on standing; the λ_{max} signals were at 238 mμ (log ε 3.98), 259 sh (3.91), 412 (3.47). This crude acridizine did not give satisfactory elemental analyses, but was pure enough for the alkylation experiment.

A suspension of 1.53 g of the crude acridizine (**8**) in 10 ml of ice cold benzyl chloride was swirled until the solid become dark and tarry. The supernatant liquid was decanted and the tarry mass dissolved in a few milliliters of ethanol. A few drops of 25% perchloric acid was added and the mixture allowed to stand for 1 week. The resulting crystals were recrystallized from ethanol. A further precipitate from the decanted benzyl chloride was purified in the same way affording a total yield of 0.73 g (21%).

This material had the identical infrared absorption spectrum and did not depress the melting point of the benzyldihydroacridizinium perchlorate obtained *via* reduction of the 11-benzylacridizinium salt (Table II).

11-Methylacridizine (**9**).—This compound was prepared in the same manner as acridizine (**8**) except that 2%, rather than 5%, sodium hydroxide solution was used. The purple product appeared to be less stable than **8** immediately after filtration and inadequate washing with water resulted in rapid decomposition. From 0.50 g of 11-methyl-6,11-dihydroacridizinium bromide 0.26 g (74%) of **9** was obtained. No solvent was found from which it could be recrystallized. The analytical sample was prepared from very pure starting material, was washed well with water, and was analyzed[11] as soon as it was dry; the λ_{max} signals were at 243 mμ (log ε 4.31), 240 (4.29), 363 (3.64), 382 (3.68), 402 (3.56).

Anal. Calcd for $C_{14}H_{13}N \cdot {}^1/_2H_2O$: C, 82.32; H, 6.90; N, 6.86. Found: C, 82.54; H, 6.69; N, 6.66.

11-Benzyl-11-methyl-6,11-dihydroacridizinium (6) Bromide.—Powdered 11-methylacridizine (0.6 g) was added with swirling to 3 ml of ice-cold benzyl bromide. A white precipitate formed which was collected by filtration and washed with acetone. After one recrystallization from methanol–ethyl acetate there was obtained 0.52 g (50%) of colorless crystals, mp 220.5–222°. The analytical sample melted at 223–225°, λ_{max} 266 mμ (log ε 3.77).

Anal. Calcd for $C_{21}H_{20}BrN$: C, 68.86; H, 5.50; N, 3.82. Found: C, 68.90; H, 5.55; N, 3.71.

11,11-Dimethyl-6,11-dihydroacridizinium (7) Perchlorate.—Powdered 11-methylacridizine (**9**, 0.68 g) was added with swirling to 3 ml of methyl iodide over a period of 3 min. The precipitate (0.41 g) which formed was collected by filtration and washed with acetone. The crude product was converted into the perchlorate salt by dissolving in water and treating with silver nitrate solution, then hydrobromic acid (to remove excess silver ion), and finally with excess perchloric acid. On cooling, 0.17 g (17%) of crystals formed, mp 192–195°. An analytical sample, mp 196–197°, was obtained by recrystallization from water, λ_{max}, 264 mμ (log ε 3.78).

Anal. Calcd for $C_{15}H_{16}ClNO_4$: C, 58.16; H, 5.21; N, 4.57. Found: C, 58.40; H, 5.25; N, 4.52.

11-Benzylacridizinium Perchlorate.—A mixture containing 8 g (0.04 mol) of 2-pyridyl benzyl ketone, 8 g (0.12 mol) of ethylene glycol, 3.2 g of *p*-toluenesulfonic acid, and 160 ml of benzene was heated under reflux for 72 hr in an apparatus provided with

(10) C. K. Bradsher and L. E. Beavers, *J. Amer. Chem. Soc.*, **78**, 2459 (1956).

(11) Analysis was by Triangle Chemical Laboratories, Chapel Hill, N. C.

a modified Dean–Stark water separator. The mixture was poured into 10% sodium carbonate solution and the benzene layer separated. The aqueous layer was extracted several times with benzene. The combined benzene layers were washed with water and dried over sodium sulfate. The solvent was removed leaving 6.5 g of oil, presumably 2-(2-benzyl[1.3]dioxolan-2-yl)pyridine. To the crude product was added 4.3 g of benzyl bromide and 2 ml of tetramethylenesulfone. The mixture was kept at 50° for 4 days and the resulting viscous oil was washed with ethyl acetate and placed in 110 g of polyphosphoric acid. The mixture was heated at 115° for 12 hr, then poured on 110 g of ice. When the ice had melted, 100 ml of water was added and the mixture was heated on a steam bath for 4 hr. The solution was treated with charcoal and after cooling 25% perchloric acid was added until precipitation was complete. The gray-green precipitate was collected and recrystallized (charcoal) twice from absolute ethanol to yield 0.66 (5%) of yellow-green crystals, mp 215–223°. An analytical sample melted at 218–223°; the λ_{max} signals were at 242 mμ (log ε 4.45), 250 (4.46), 366 (3.82), 382 (3.83), 404 (3.78).

Anal. Calcd for $C_{20}H_{16}ClNO_4$: C, 64.95; H, 4.36; N, 3.79. Found: C, 64.86; H, 4.41; N, 3.90.

7,13-Dihydrobenz[*h*]acridizinium (12) Bromide.—The reduction of benz[*h*]acridizinium bromide[10] was carried out in 37% yield essentially as in the hydrogenation of acridizinium bromide. The product was colorless: mp 240–258°; λ_{max} 267 mμ (log ε 4.04); nmr (D_2O), δ 4.28 (S, 2, CH_2, C-7), 5.40 (S, 2, CH_2, C-13).

Anal. Calcd for $C_{17}H_{14}BrN$: C, 65.40; H, 4.52; N, 4.49. Found: C, 65.12; H, 4.50; N, 4.44.

The **perchlorate** had mp 167.5–171°.

Anal. Calcd for $C_{17}H_{14}ClNO_4$: C, 61.54; H, 4.25; N, 4.22. Found: C, 61.31; H, 4.19; N, 4.19.

Registry No.—**1**, X = Br, 15757-24-1; **1**, X = ClO_4, 15815-87-9; **2**, X = Br, 15757-25-2; **2**, X = ClO_4, 15815-88-0; **3**, X = ClO_4, 15815-89-1; **4**, X = Br, 15757-26-3; **4**, X = ClO_4, 15815-90-4; **5**, X = Br, 15757-27-4; **5**, X = ClO_4, 15892-89-4; **6**, X = Br, 15757-28-5; **7**, X = ClO_4, 15815-91-5; **8**, 260-61-7; **9**, 15815-92-6; **12**, X = Br, 15757-29-6; **12**, X = ClO_4, 15815-93-7; 11-benzylacridizinium perchlorate, 15815-94-8.

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Alkylation of Alkali Metal Salts of Pyrrole with Allyl and *n*-Propyl Tosylate

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In the course of a study of the factors affecting the position of alkylation of ambident anions, the reaction of alkali metal salts of pyrrole with allyl tosylate was investigated to evaluate the effectiveness of the latter as an alkylating agent.

The product of this reaction was a mixture of the isomeric allylpyrroles and higher boiling compounds which are presumed to be diallylpyrroles. In general, the composition of the product paralleled the one observed earlier in the reaction of alkali metal salts of pyrrole with allyl bromide.[1] In the present work, however, the N/C alkylation ratios, expressed in terms of the relative percentages of 1-, 2-, and 3-allylpyrrole, were considerably higher (Table I). It should be noted that the actual amount of carbon alkylation is higher than these numbers indicate, because of the further reaction of part of the initially formed 2- and 3-allylpyrrole to yield diallylpyrroles.[1,2] Nonetheless, there is a significant difference in selectivity between the two alkylating reagents allyl tosylate and allyl bromide.

TABLE I

REACTIONS OF PYRROLYLMETAL SALTS WITH ALLYL TOSYLATE AND ALLYL BROMIDE AT 65°

		Relative %					
		1-Allyl-pyrrole		2-Allyl-pyrrole		3-Allyl-pyrrole	
Cation	Solvent	*a*	*b*	*a*	*b*	*a*	*b*
K^+	Dimethyl sulfoxide	99	89	0.50	8.0	0.50	3.0
K^+	Tetrahydrofuran	86	80	11	18	3.0	2.0
K^+	Benzene	66	14	25	80	9.0	6.0
Na^+	Tetrahydrofuran	30	19	54	77	16	4.0
Na^+	Tetrahydrofuran (inverse addition)	72	36	22	58	6.0	6.0
Li^+	Tetrahydrofuran	24	1.0	59	90	17	9.0

[a] Reaction with allyl tosylate. [b] Reaction with allyl bromide (see ref 1 and 11).

The effect of the leaving group on the position of alkylation of ambident anions has been studied in relatively few cases and seems to vary. Thus, a change in the leaving group from Cl^- to Br^- to I^- has been reported to have no effect on product composition in the reaction of the sodium salt of 2,6-dimethylphenol with allyl and benzyl halides.[3] Similarly, no effect has been observed in the reaction of the lithium salt of 2-nitropropane with benzyl halides in dimethylformamide.[4] On the other hand, the same change in the leaving group has been found to decrease the yield of O-alkylated product in the reaction of the potassium, or sodium salt of ethyl acetoacetate with alkyl halides in dimethylformamide,[5] or dimethyl sulfoxide,[6] and in the reaction of the sodium salt of 2-carbethoxycoumaran-3-one with benzyl and *m*-nitrobenzyl halides in dimethylformamide.[7] In the same way, a change from Br^- to I^- causes a decrease in N alkylation in the reaction of the sodium salt of indole with alkyl halides.[2]

Tables I and II show that a change to more polar solvents increased the N/C alkylation ratio in the reaction of pyrrolylpotassium with allyl tosylate. This trend is in agreement with previous observations that aprotic solvents of higher ability to solvate cations favor

TABLE II

EFFECT OF TEMPERATURE ON THE REACTION OF PYRROLYLPOTASSIUM WITH ALLYL TOSYLATE

		Relative %		
Solvent	Temp, °C	1-Allyl-pyrrole	2-Allyl-pyrrole	3-Allyl-pyrrole
Dioxane	50	82	13	5.0
Dioxane	75	86	11	3.0
Dioxane	100	89	9.0	2.0
Toluene	50	47	37	16
Toluene	75	53	33	14
Toluene	100	62	25	13

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