

$1.19 \pm 0.10$ , and not sensibly a function of acidity (0.05–1.00 *N*), showing that deuterons are favored over protons by 20% inside the molecular cavity.

The equilibrium and rate constants of the isomerization of the [7.7.7] and [8.8.8] ammonium ions are not influenced by the nature of the counterion; however, this is no longer so when the hydrocarbon chains contain nine or more methylenes due to a remarkable kind of ion pairing in the larger ammonium ions.<sup>4</sup>

(4) C. H. Park and H. E. Simmons, *J. Am. Chem. Soc.*, **90**, 2431 (1968).

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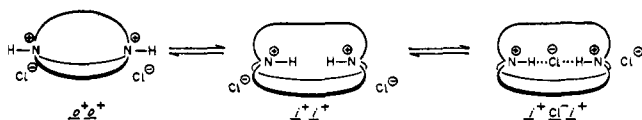
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### Macrobicyclic Amines. III. Encapsulation of Halide Ions by *in, in*-1, (*k* + 2)-Diazabicyclo[*k.l.m*]alkane-ammonium Ions

Sir:

Certain *in, in*-1, (*k* + 2)-diazabicyclo[*k.l.m*]alkane-ammonium ions<sup>1,2</sup> (*k* = *l* = *m* ≥ 9) exhibit an unprecedented kind of ion pairing in aqueous media which involves diffusion of halide ions into the hydrocarbon cavity. This encapsulation does not occur in the smaller ammonium ions; furthermore, the *o*<sup>+</sup>*o*<sup>+</sup> and *i*<sup>+</sup>*i*<sup>+</sup> ions generally show no appreciable ion pairing in the usual sense, as judged from pmr concentration studies with a variety of anions.

*out, out*-1,11-Diazabicyclo[9.9.9]nonacosane bis(deuteriochloride), dissolved in 50% deuteriotrifluoroacetic acid (DTFA), is slowly converted to the *in, in* isomer (*K*<sub>e</sub> = 0.41),<sup>1</sup> and subsequently a second equilibrium is established more slowly to produce a new monocation. The three ions are readily distinguished by their 220-MHz pmr spectra: the α-CH<sub>2</sub> absorptions occur at 2.90 (multiplet) in *o*<sup>+</sup>*o*<sup>+</sup>, 3.07 (triplet) in *i*<sup>+</sup>*i*<sup>+</sup>, and 2.80 ppm (triplet) in the monocation. In another experiment, 1.0 equiv (2 moles) of chloride ion (DCl, NaCl, or LiCl) was added to an equilibrium mixture of the *o*<sup>+</sup>*o*<sup>+</sup> and *i*<sup>+</sup>*i*<sup>+</sup> bis(trifluoroacetates) in 50% DTFA at 23°. The spectrum was unchanged shortly after mixing, but during several days the absorption at 2.80 ppm emerged (Figure 1a,b). The spectrum sharpened on heating at 65°, and all three absorptions were well differentiated (Figure 1c). This shows that the equilibrium constant of *o*<sup>+</sup>*o*<sup>+</sup> ⇌ *i*<sup>+</sup>*i*<sup>+</sup> is not disturbed and that interconversion of the monocation with either isomer is slow on the nmr time scale, even at elevated temperatures. Furthermore, basification gives quantitative recovery of the amine.



These experiments establish that the new cation is formed with considerable chemical activation, and they are consistent with encapsulation of chloride ion

(1) H. E. Simmons and C. H. Park, *J. Am. Chem. Soc.*, **90**, 2428 (1968).

(2) C. H. Park and H. E. Simmons, *ibid.*, **90**, 2429 (1968).

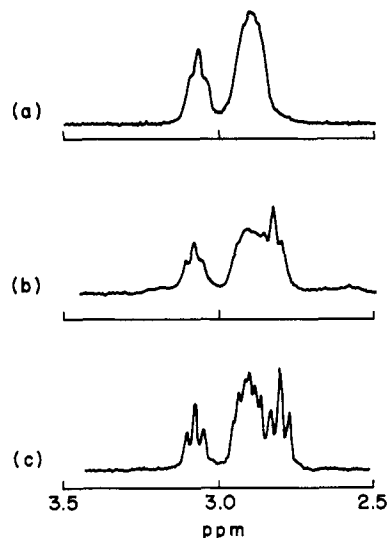


Figure 1. Pmr spectra (220 MHz) of α-CH<sub>2</sub> absorptions of 1,11-diazabicyclo[9.9.9]nonacosane in 50% DTFA; equilibrium mixture of *o*<sup>+</sup>*o*<sup>+</sup> and *i*<sup>+</sup>*i*<sup>+</sup> isomers to which 1.0 equiv of NaCl has been added; (a) *t* = 1 min, 23°; (b) *t* = 21 days, 23°; (c) *t* = 21 days, 65°.

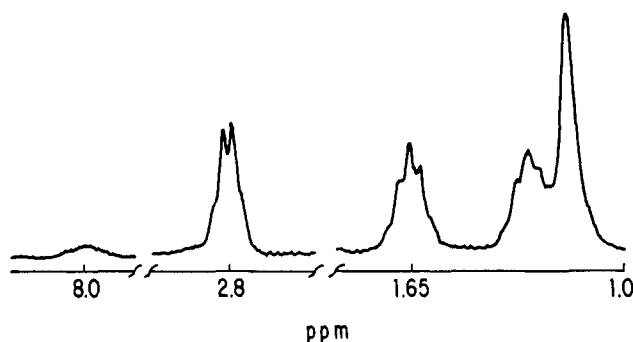


Figure 2. Pmr spectrum (220 MHz) of chloridkatapinate-*in, in*-1,11-diazabicyclo[9.9.9]nonacosanebis(ammonium) chloride in 50% DTFA at *t* = 12 min, 23°.

in the molecular cavity of an *in, in* isomer. The NH<sup>+</sup> absorption (2 H) of this bishydrochloride occurs at 8.0 ppm in 50% TFA, and the large downfield shift from the *i*<sup>+</sup>*i*<sup>+</sup> ion (4.8 ppm)<sup>1</sup> can be accounted for by hydrogen bonding with the chloride ion. The upfield shift of the α-CH<sub>2</sub> resonance in the monocation can be explained in terms of anisotropic shielding effects of the ellipsoidally polarized chloride ion within the cavity.

A new, crystalline bishydrochloride deposited when a solution of the [9.9.9] amine in 10% HCl was allowed to stand 5 days at 25°. The 220-MHz spectrum of this bishydrochloride in 50% TFA immediately after solution showed the presence of only the katapinate<sup>3</sup> *i*<sup>+</sup>Cl<sup>−</sup>*i*<sup>+</sup>-[9.9.9] Cl<sup>−</sup> (Figure 2). When this solution was allowed to stand, the equilibria among *o*<sup>+</sup>*o*<sup>+</sup>, *i*<sup>+</sup>*i*<sup>+</sup>, and *i*<sup>+</sup>Cl<sup>−</sup>*i*<sup>+</sup> are slowly reestablished. Bromide ion is encapsulated by *i*<sup>+</sup>*i*<sup>+</sup>-[9.9.9] less favorably than chloride, and no encapsulation of iodide can be detected (Table I).

(3) We define katapinosis (Greek, καταπινω = swallow up, engulf) as diffusion of molecules into a larger molecule with a sensible cavity to give a discrete molecular species. An appropriate name for the complex ammonium ion is chloridkatapinato-*in, in*-1,11-diazabicyclo[9.9.9]nonacosanebis(ammonium) chloride (a chloridkatapinate chloride) or simply *i*<sup>+</sup>Cl<sup>−</sup>*i*<sup>+</sup>-[9.9.9] Cl<sup>−</sup>.

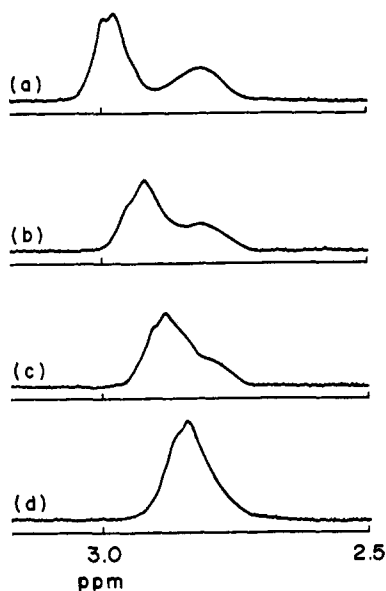


Figure 3. PMR spectra (220 MHz) of  $\alpha$ -CH<sub>2</sub> resonances observed in equilibrium mixture of  $o^+o^+$  and  $i^+i^+$ -[10.10.10] bis(trifluoroacetates) in 50% TFA at 23° containing added NaCl: (a) 0.0 equiv; (b) 0.5 equiv; (c) 1.0 equiv; and (d) 2.0 equiv.

Differences in the behavior of the larger  $i^+i^+$ -[10.10.10] ion further clarify the encapsulation phenomenon. The  $o^+o^+ \rightleftharpoons i^+i^+$  equilibrium of the [10.10.10] amine in 50% TFA favors the  $i^+i^+$  isomer ( $K_e = 3.3$ ),<sup>1</sup> and the  $\alpha$ -CH<sub>2</sub> resonances occur at 2.82 ( $o^+o^+$ ) and 2.98 ppm ( $i^+i^+$ ). When 0.5 equiv of chloride ion is added to the mixture at 23°, the  $i^+i^+$  resonance is instantaneously shifted upfield to 2.92 ppm, whereas no change in position or intensity is detected in the  $o^+o^+$  resonance. The addition of 1.0 equiv of chloride to the original mixture shifts the  $i^+i^+$  resonance to 2.87 ppm, and 2.0 equiv to 2.84 ppm, after which no further change is noted on addition of excess chloride (Figure 3). These observations mean that in  $i^+i^+$ -[10.10.10] relative to  $i^+i^+$ -[9.9.9]: (1) the forward and reverse rate constants for  $i^+i^+ + \text{Cl}^- \rightleftharpoons i^+\text{Cl}^-i^+$  are much larger, so that only a time-average absorption is detected, and (2) the encapsulation equilibrium constant is large, since the upfield shifts of the  $\alpha$ -CH<sub>2</sub> are proportional to the amount of added chloride. Both bromide and iodide are encapsulated rapidly by  $i^+i^+$ -[10.10.10], and similar time-average spectra were observed. This suggests that the size of the cavity is an important factor in halide katapinosis. The halide radii and cavity diameters, measured on CPK models, are compared in Table I.<sup>4</sup>

Table I. Equilibrium Constants<sup>a</sup> for Halide Encapsulation by *in, in*-1, (*k* + 2)-Diazabicyclo[*k.k.k*]alkaneammonium Ions

Halide	$r_{\text{ionic}}, \text{\AA}$	$K, M^{-1}$			
		[7.7.7]	[8.8.8]	[9.9.9]	[10.10.10]
Cl <sup>-</sup>	1.81	0	0	4	>10
Br <sup>-</sup>	1.95	0	0	1	>10
I <sup>-</sup>	2.16	0	0	0	>10
Cavity diameter, $\text{\AA}^b$		1.6	2.8	3.6	4.5

<sup>a</sup>  $K$  for  $i^+i^+ + \text{Hal}^- \rightleftharpoons i^+\text{Hal}^-i^+$ . <sup>b</sup> The cavity diameter was measured with CPK models and is defined as the distance between the faces of "hydrogen-bond" protons in the  $i^+i^+$  isomer.

The stability of the katapinate ions must arise in part from the high positive potential of the hole with respect to anions and from hydrogen bonding within the cavity, [ $^+\text{N}-\text{H} \cdots \text{Cl}^- \text{H}-\text{N}^+$ ] or [ $^+\text{N}-\text{H} \cdots \text{Cl}^- \cdots \text{H}-\text{N}^+$ ]; it is not unlikely that the latter structure with two hydrogen bonds is involved. It is anticipated that polarizability, heat of hydration, and charge of the anion are also important. Furthermore, there is evidence, to be reported soon, that the encapsulated chloride ion exchanges rapidly with external chloride ion and that the chemical activations observed in encapsulation arise from a prior conformational change in the  $i^+i^+$  ion. The diffusion step, however, may require significant activation with larger anions.

(4) Addition of sodium fluoride to equilibrium mixtures of  $o^+o^+$  and  $i^+i^+$  bis(trifluoroacetates) in water caused the free amine to precipitate due to the high basicity of fluoride ion; in acidic media, bifluoride ion formation obscures encapsulation. The high heat of hydration of fluoride ion may also hinder katapinosis.

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## Stable Halo Enamines. Possible S<sub>N</sub>1-Type Solvolysis

Sir:

Enamines have been studied intensively and are widely used in synthesis.<sup>1</sup> However, there are but a few reports on halogenation of enamines.<sup>2</sup> To our knowledge there is no previously reported successful isolation of halo enamines. We have successfully synthesized and isolated 1-bromo-2-(4-morpholino)-1,2-diphenylethene (I) and 1-chloro-2-(4-morpholino)-1,2-diphenylethene (II).<sup>3</sup> These compounds are crystalline and can be kept under nitrogen at room temperature for weeks.

Reactions of the *cis* form of 1-(4-morpholino)-1,2-diphenylethene (III)<sup>4</sup> with N-bromosuccinimide and N-chlorosuccinimide in benzene under nitrogen at room temperature gave I in 79% yield and II in 65% yield, respectively. Both I and II were isolated as mixtures of *cis* and *trans* isomers.

Table I. Nmr Spectra of Enamines<sup>a</sup>

	Chemical shift of morpholino hydrogens	
	2,6-	3,5-
<i>cis</i> -I	218	181
<i>trans</i> -I	204	150
<i>cis</i> -II	218	182
<i>trans</i> -II	205	150
<i>cis</i> -III	217	167

<sup>a</sup> Recorded for solution in carbon tetrachloride with tetramethylsilane as the internal standard on a Varian A-60 instrument. All chemical shifts are given in cycles per second downfield from TMS. The 2,6-hydrogen and 3,5-hydrogen signals appear as two triplets with a coupling constant of 5 cps.

(1) For reviews on enamines, see: (a) K. Bla'ha, *Advan. Heterocyclic Chem.*, **6**, 147 (1966); (b) J. Szmuskovicz, *Advan. Org. Chem.*, **4**, 1 (1963).

(2) (a) R. L. Pederson, J. L. Johnson, R. P. Holysz, and A. C. Off, *J. Am. Chem. Soc.*, **79**, 1115 (1957); (b) I. J. Borowitz, as cited by Szmuskovicz in ref 1b.

(3) Structures for both compounds are sustained by elemental analyses and mass spectra, as well as by ultraviolet, infrared, and nmr spectra.

(4) M. E. Munk and Y. K. Kim, *J. Org. Chem.*, **30**, 3705 (1965).