PYRAMIDAL INVERSION OF SULFONIUM IONS. THE
RACEMIZATION OF 1-ADAMANTYLETHYLMETHYLSULFONIUM PERCHLORATE

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Thermal racemization of optically active sulfonium salts may proceed by three routes:

pyramidal inversion ($\underset{\sim}{A}$), dissociation by a $S_N1$ mechanism ($\underset{\sim}{B}$), or dissociation by a $S_N2$ ($\underset{\sim}{C}$)

mechanism:



Pathway $\underset{\sim}{C}$ has been proposed (1) for the racemization of optically active phenacyl-

ethylmethyl sulfonium iodide, and $\underset{\sim}{A}$ has been described (2) as the "major pathway" for the

racemization of t-butylethylmethylsulfonium perchlorate (I); in this reaction pathway $\underset{\sim}{C}$

is eliminated by virtue of the low nucleophilicity of the perchlorate ion. However, solvo-

lysis which accompanies racemization of I (e.g., in ethanol, $k_\alpha^{50}$ = 4.71 x $10^{-4}$ sec.$^{-1}$ and

$k_t^{50}$ = 4.51 x $10^{-5}$ sec.$^{-1}$) is indicative of carbon-sulfur bond heterolysis and implies the

possible intervention of pathway $\underset{\sim}{B}$ in the racemization. On the basis of a comparison of the

rate constants of racemization ($k_\alpha$) and solvolysis ($k_t$) of various derivatives of I, Darwish

and Tourigny (2) concluded that, taking into account the presumed effect of substituents on

$k_\alpha$ and $k_t$, pathway $\underset{\sim}{B}$ is of minor importance.

We have tested this conclusion by a study of the racemization of 1-adamantylethylmethyl-

sulfonium perchlorate (II): since rates of solvolysis of 1-adamantyl halides are slower than

those of the corresponding t-butyl derivatives by a factor of $10^3$ (3), pathway $\underset{\sim}{B}$ should be

of negligible importance in II as compared with I.

Ethyl iodide was added to a solution of 1-adamantanethiol (m.p. 100-102° (4)) in

ethanol containing one equivalent of sodium ethoxide to yield, after workup, 1-adamantyl ethyl sulfide (III), b.p. 100-105° (0.5 mm). Anal. calcd. for $C_{12}H_{20}S$: C, 73.40; H, 10.27. Found: C, 73.51; H, 10.33. One equivalent of silver perchlorate was added at room temperature to a solution of III in a ten-fold molar excess of methyl iodide; methylene chloride was added, silver iodide was removed by filtration, and the filtrate was worked up to yield an oil which readily crystallized to give II, m.p. 161-163° after recrystallization from acetone-ether. Anal. calcd. for $C_{13}H_{23}SClO_4$: C, 50.24; H, 7.41; S, 10.31. Found: C, 49.47; H, 7.48; S, 10.41. The n.m.r. spectrum featured a triplet at $\tau$ 8.44 (J = 7 Hz, 3 H) assigned to $\text{\char`\>}S$ - $CH_2C\underline{H}_3$, a complex multiplet in the range $\tau$ 7.50 - 8.33 (15 H) assigned to the adamantyl protons, a singlet at $\tau$ 7.16 (3 H) assigned to S - $C\underline{H}_3$, and the AB portion of a $ABX_3$ multiplet centered at $\tau$ 6.66 (2 H) assigned to $\text{\char`\>}S$ - $C\underline{H}_2CH_3$ (5). A solution of II in methanol-water (15:85) was passed through a column of Amberlite IR A-400 (Mallinckrodt) which had been pretreated by exchange of chloride by hydroxide and the eluate was reacted with two equivalents of (-)-malic acid in the same solvent. The solvent was removed at reduced pressure below 25° and the residual salt was recrystallized three times from acetone-ether to give 1-adamantylethylmethylsulfonium acid malate (IV), m.p. 108-111°, $[\alpha]_D$ + 8.1° ($\underline{c}$ 1.3, methanol), $[\alpha]_D$ + 47.0° ($\underline{c}$ 1.6, chloroform). Anal. calcd. for $C_{17}H_{28}O_5S$: C, 59.30; H, 8.13; S, 9.30. Found: C, 58.99; H, 8.35; S, 9.26. A solution of IV in methanol-water was passed through a column of Amberlite IR A-400 and one equivalent of silver perchlorate was added to the eluate. After filtration of the silver chloride the solvent was removed at reduced pressure below 25° to give optically active II, m.p. 159-160°, $[\alpha]_D$ + 5.93° ($\underline{c}$ 2.5, methanol), whose n.m.r. spectrum was identical in every respect with that of racemic material. Anal. found: C, 50.24; H, 7.59; S, 10.11. The optical purity of (+)-II is unknown.

Rates of racemization of II were measured on 0.01-0.03 $\underline{M}$ solutions in acetic acid under conditions where, even after initial periods of temperature equilibration lasting from 30 to 45 min., $\alpha$ was about 0.05-0.10° ($\lambda$ = 360 m$\mu$, $\ell$ = 1 dm) and the change of $\alpha$ as a function of time could be conveniently followed with a precision of ± 0.0005° over a period of 2-6 half-lives (Cary 60 spectropolarimeter). First order rate constants obtained were as follows: $k_\alpha$ x $10^4$ (sec.$^{-1}$) = 0.98 (at 34°), 2.71 (at 41°), and 8.59 (at 50°).

As expected, II does not solvolyze under the conditions of the racemization. Thus, a 0.033 $\underline{M}$ solution of II in acetic acid containing 0.068 mole/l. of sodium acetate does not

perceptibly solvolyse at $50^o$ over a period of observation of 138 hr. In striking contrast,

a 0.029 $\underline{M}$ solution of I in acetic acid containing 0.054 mole/l. of sodium acetate solvolyses

at $50^o$ with first order kinetics over the period of measurement (6.5 hr., 1.3 half-lives),

$k_t$ = 3.95 x $10^{-5}$sec.$^{-1}$ (lit.(2) $k_t^{50}$ = 3.62 x $10^{-5}$sec.$^{-1}$, $k_\alpha^{50}$ = 4.13 x $10^{-4}$sec.$^{-1}$). A 0.041

$\underline{M}$ solution of I in acetic acid not containing sodium acetate has an initial $k_t$ at $50^o$ of

3.48 x $10^{-5}$sec.$^{-1}$; after about 1 hr., when ca. 15% of the sulfonium salt has been consumed,

the reaction slows perceptibly, and after 6 hr., when about 24% of the sulfonium salt has

been consumed, solvolysis has essentially ceased.

In a further test for the possible intervention of pathway $\underline{B}$, the following experiment

was performed. 1-Adamantylethyl-$\underline{d}_5$-methylsulfonium perchlorate (V) was prepared from 1-

adamantanethiol and ethyl-$\underline{d}_5$ bromide as described for the undeuterated analog II; the n.m.r.

spectrum of V was identical with that of II except for the absence of the methyl triplet at

$\tau$ 8.44 and the methylene multiplet at $\tau$ 6.66. A solution of 0.193 mmole of V and 0.915

mmole of ethyl methyl sulfide in 9 ml. of acetic acid was heated for 3 hr. at $50^o$; after

workup, the n.m.r. spectrum of recovered (76.6%) sulfonium salt was indistinguishable from

that of starting V.

In summary, our experiments yield no evidence for carbon-sulfur bond cleavage in II,

corresponding to pathway $\underline{B}$. Pathway $\underline{C}$ is eliminated for the same reason as in I (2). While

we cannot on the basis of our data rule out the possibility that racemization proceeds by an

ion-molecule heterolysis-internal return mechanism, the lack of solvolysis and isotope ex-

change under the conditions employed in the racemization provides negative evidence against

that eventuality. More convincingly, the rate constants of racemization of I ($k_\alpha^{50}$ = 4.13 x

$10^{-4}$sec.$^{-1}$) and II ($k_\alpha^{50}$ = 8.59 x $10^{-4}$sec.$^{-1}$) in acetic acid are comparable in magnitude;

since the steric effects of $\underline{t}$-butyl and adamantyl groups are probably quite similar whereas

the stabilities of the corresponding carbonium ions differ by several orders of magnitude (3),

this result would be difficult to reconcile if pathway $\underline{B}$ were the mechanism of racemization.

The single hypothesis which suffices to account for all of the presently available evidence

is that racemization of I and II proceeds by pyramidal inversion, i.e., by pathway $\underline{A}$.

The process of pyramidal inversion is considerably more facile for sulfonium salts I and

II than for comparable sulfoxides (6); for example, $k_\alpha$ for 1-adamantyl methyl sulfoxide (7)

is 1.1 x $10^{-5}$sec.$^{-1}$ at $\underline{210}^o$ (solvent $\underline{p}$-xylene). The distinction in the behavior of the two

systems is reflected in the activation parameters for racemization: whereas $\Delta H^{\ddagger}$ for comparable sulfoxides (6) is of the order of 35-40 kcal/mole ($\Delta S^{\ddagger} \approx 0$), the corresponding values for II are $\Delta H^{\ddagger}$ 26 kcal/mole and $\Delta S^{\ddagger}$ + 8 e.u.  Solvation effects may play an important role in determining the pyramidal stability of sulfonium salts.  This view accommodates the relatively greater configurational stability of phosphines, e.g., of methyl phenyl n-propyl phosphine which has a half-life of 5 hr. at $130^{\circ}$ (8): the phosphines are uncharged species and their racemization would be expected to be less susceptible to solvation effects than that of their isoelectronic but charged counterparts, the sulfonium ions.

References:

    1.  M. P. Balfe, J. Kenyon, and H. Phillips, J.Chem.Soc. 2554 (1930)

    2.  D. Darwish and G. Tournigny, J.Amer.Chem.Soc. 88, 4303 (1966)

    3.  P. von R. Schleyer and R. D. Nicholas, J.Amer.Chem.Soc. 83, 2700 (1961)

    4.  J. R. Geigy A.-G. Belg.Pat. 629, 370 (Oct. 21, 1963)

    5.  The chemical shift nonequivalence of diastereotopic protons in sulfonium salts has been recently discussed by K. Kondo and K. Mislow, Tetrahedron Letters No. 14, 1325 (1967)

    6.  D. R. Rayner, E. G. Miller, P. Bickart, A. J. Gordon, and K. Mislow, J.Amer.Chem.Soc. 88, 3138 (1966)

    7.  D. R. Rayner, unpublished results

    8.  L. Horner and H. Winkler, Tetrahedron Letters No. 9, 461 (1964)