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SOLVOLYSIS OF CROWDED 2-ADAMANTYL DERIVATIVES: COMPARISON WITH THE 2-NORBORNYL SYSTEM

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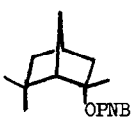
Solvolyses of secondary and tertiary 2-adamantyl derivatives are remarkably free from solvent assistance and neighboring group participation.[1] Furthermore, the rigid adamantyl structure lacks appreciable angle and torsional strain.[2] We now report the effects of steric crowding by meta-axial methyl groups on the solvolysis of secondary and tertiary 2-adamantyl derivatives.[3] These results are useful in interpreting the behavior of the corresponding 6,6-dimethyl-2-norbornyl (1-4)[4] and 7,7-dimethyl-2-norbornyl derivatives (5-8).[4b]



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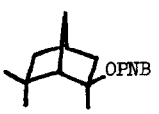

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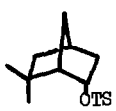

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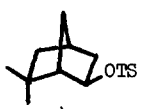

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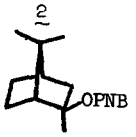

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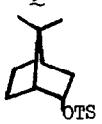

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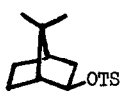

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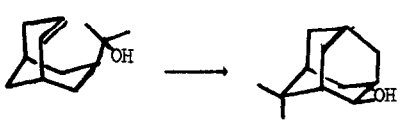
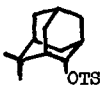
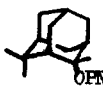
Synthesis of alcohols 9-OH, 10-OH, 11-OH and 12-OH proved straightforward. Known alcohol 13[5] cyclized in high yield on exposure to hot formic acid producing 9-OH[5b,c]. The ketone from Jones oxidation of 9-OH is attacked predominately on the side away from the bulky



13 → 9-OH

Table I. First Order Rate Constants of Adamantyl Derivatives

Compound	Temp. (°C)	k^a (sec^{-1})	$\Delta H^{\ddagger}$ (kcal/mole)	$\Delta S^{\ddagger}$ (e.u.)	k_{rel} (75°)
 10 OTS	24.85 51.42 75.0	1.70×10^{-5} d 6.15×10^{-4} d 9.44×10^{-3} b	25.3	4.6	63
 9 OTS	74.95 100.22 75.0	3.22×10^{-4} d 4.07×10^{-3} d 3.24×10^{-4} b	25.2	-2.4	2.2
 14 OTS	76.63 100.11 75.0	1.78×10^{-4} d 1.95×10^{-3} d 1.49×10^{-4} b	25.7	-2.4	1.0
 11 OPNB	102.1 84.2 75.0	5.24×10^{-5} e 9.29×10^{-6} e 3.58×10^{-6} b	25.0	-5.3	14
 12 OPNB	65.6 50.0 75.0	3.20×10^{-5} e 5.16×10^{-6} e 8.95×10^{-5} b	24.9	+0.9	350
 15 OPNB	100.0 124.8 75.0	5.07×10^{-6} c,e 6.88×10^{-5} c,e 2.54×10^{-7} b	30.2	-2.2	1.0

[a] Determined conductimetrically unless otherwise noted. [b] Calculated. [c] Determined titrimetrically. [d] 60% Ethanol. [e] 80% Acetone.

Table II. Relative Rates of Norbornyl Derivatives

Compound	k_{rel} (75°)
2,6,6-Trimethyl-2-endo-norbornyl p-nitrobenzoate, 1	0.24 a
2-Methyl-2-endo-norbornyl p-nitrobenzoate, 18	1.0 a
2,7,7-Trimethyl-2-endo-norbornyl p-nitrobenzoate, 5	197 b
2,6,6-Trimethyl-2-exo-norbornyl p-nitrobenzoate, 2	338 a
2-Methyl-2-exo-norbornyl p-nitrobenzoate, 19	1.0 a
2,7,7-Trimethyl-2-exo-norbornyl p-nitrobenzoate, 6	0.025 b
6,6-Dimethyl-2-endo-norbornyl tosylate, 3	0.1 c
2-endo-Norbornyl tosylate, 16	1.0 c
7,7-Dimethyl-2-endo-norbornyl tosylate, 7	0.8 d
6,6-Dimethyl-2-exo-norbornyl tosylate, 4	0.07 c
2-exo-Norbornyl tosylate, 17	1.0 c
7,7-Dimethyl-2-exo-norbornyl tosylate, 8	8.7 d

[a] Reference 4, 80% acetone [b] Reference 4b, 80% acetone [c] Reference 10, acetic acid [d] S. Winstein, N.J. Holness, J. Amer. Chem. Soc., 77, 3054 (1955); P.v.R. Schleyer, W.E. Watts, C. Cupas, ibid, 86, 2722 (1964); k_{rel} for brosylates in acetic acid.

gem dimethyl group. Thus, $LiAlH_4$ reduction produced 10-OH[sc] and methyl Grignard gave 11-OH. Dehydration of 11-OH followed by epoxidation and reduction with $LiAlH_4$ gave 12-OH.

Inductive effects of the γ, γ-dimethyl groups in γ-12 should be small.[6] No significant σ-bond participation is expected[7] and no protoadamantyl products were detected. The observed rate effects should be largely steric in origin.

Relief of ground state 1,3-diaxial interactions adequately accounts for the relative rates of the adamantyl derivatives in Table I. Thus, 9 solvolyzes 2.2 times faster than 2-adamantyl tosylate 14 due to relief during ionization of one axial CH_3...H skew interaction, estimated to be 1.0-1.3 kcal/mole.[8] Likewise, tertiary 12 is enhanced 350-fold over 15. The magnitude of a 1,3 CH_3...CH_3 interaction in adamantane is unknown; in cyclohexane it is worth 3.7 kcal/mole.[9] Similar rate enhancements, 338 and 197, occur with exo norbornyl derivative 2 and endo-5, respectively (Table II). The secondary analog 4, however, solvolyzes only 0.07 times as fast as exo-2-norbornyl tosylate 17, a fact attributed to steric inhibition of σ- participation.[10] Such participation is absent in both 9 and 14.

The behavior of endo compounds 10 and 11 is unpredictable since the locus of departure of the leaving group in going from ground to transition state is unknown.[4] The leaving group could either come closer to the axial γ-methyl, increasing strain, or move farther away, relieving ground state strain. A 1,3-diaxial OH...CH_3 interaction in the cyclohexane series lies in the range 1.9-2.4 kcal/mole.[9] In fact, 11 is accelerated 14-fold, 10 63-fold, and in the norbornyl series, 8 8.7 fold. Clearly, ground state congestion is relieved on ionization, this relief being larger for the secondary tosylate, 10, than for the tertiary p-nitrobenzoate, 11.

In contrast to the adamantyl series, endo norbornyl derivatives 3, 1, and 7 are slowed by factors of 0.1, 0.2, and 0.8 respectively, while exo-6 is retarded by 0.025. Closer approach of tosylate to the methyl group in the transition state of 3 may be the reason for the deceleration. Alternatively, endo-norbornyl tosylate, 16, may have a significant k_s contribution to the rate.[11] In 3, solvent assistance should be unfavorable since the pentacoordinate k_s transition state would direct the leaving group closer to the endo-6-methyl. Similarly, approach of the solvent from the rear may be blocked in 7. Thus 3 and 7 may be reacting by different mechanisms than 16. The rate depressions of 1 and 6, however, imply an increased CH_3...OTs nonbonded interaction in the transition state.

The disparate solvolytic relative rate behavior of seemingly similar pairs of adamantyl and norbornyl derivatives, especially 10 vs 3, 11 vs 1 and 9 vs 4 illustrates the sensitivity of

both the direction and magnitude of steric effects towards the exact transition state geometry. We hope to extend our computer rate program[3] to encompass such situations predictively.

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