2, 128.1 (d) × 2, 127.3 (d) × 2, 127.2 (d), 112.2 (d) × 2, 72.7 (u), 66.7 (u), 66.3 (u), 63.8 (d), 54.8 (d), 47.0 (u), 39.7 (u), 39.6 (u), 39.5 (u), 38.0 (u), 37.8 (u), 34.9 (u), 33.2 (u), 31.9 (d); IR 3031, 2955, 2928, 1609, 1549, 1514, 1464, 1454, 1364, 1254, 1190, 1101, 1041; MS (CH_4, CI) 507 ($M + H^+$) (4), 401 (14), 399 (16), 323 (10), 205 (15), 151 (11), 147 (21), 121 (21), 119 (64), 107 (43), 91 (100); $[\alpha]^{25}_D = +7.4$ ($c = 0.012$, $CHCl_3$).

(*S*)-4-(4-Methoxyphenyl)-4-[2-(phenylmethoxy)eth-1-yl]-cyclohex-2-en-1-one (15). Red mercuric oxide (0.235 g, 1.08 mmol, 4.1 equiv) and boron trifluoride etherate (0.13 mL, 1.06 mmol, 4 equiv) were combined, followed 1 min later by THF/H_2O (0.6 mL of an 85:15 mixture). The orange suspension was stirred 10 min, and then compound **14** (0.134 g, 0.265 mmol) in THF (0.3 mL) was added dropwise. After 70 min the reaction mixture was diluted with water (0.5 mL) and filtered through a pipet of silica gel. The resulting liquid was extracted with ethyl acetate (3 × 0.5 mL). The combined organic extract was dried ($MgSO_4$), concentrated in vacuo, and diluted with toluene (1.5 mL). *p*-Toluenesulfonic acid (20 mg, 0.105 mmol) was added, and the mixture was warmed to reflux for 4 h. The reaction mixture was evaporated directly onto 60–200-mesh silica gel and then chromatographed, to give **15** (62 mg, 0.185 mmol, 70% yield based on **14**) as a colorless oil: R_f (30% EtOAc/hexanes) = 0.55; ^{1}H NMR δ 7.28–7.15 (m, 8 H), 6.81 (d, J = 8.9 Hz, 2 H), 6.08 (d, J = 10.3 Hz, 1 H), 4.33 (s, 2 H), 3.75 (s, 3 H), 3.37 (t, J = 6.6 Hz, 2 H), 2.40–2.10 (m, 6 H); ^{13}C NMR δ 199.4 (u), 158.3 (u), 156.1 (d), 138.1 (u), 134.9 (u), 129.0 (d), 128.4 (d), 127.7 (d), 127.60 (d), 127.56 (d), 114.0 (d) × 2, 73.1 (u), 66.9 (u), 55.2 (d)8 42.7 (u), 41.2 (u), 36.4 (u), 34.5 (u); IR 3068, 2951, 2927, 1732, 1609, 1580, 1551, 1515, 1454, 1254, 1190, 1101, 1043, 1009, 979; MS 336 (M^+) (37), 245 (12), 202 (40), 201 (100), 187 (11), 173 (17), 159 (10), 158 (11), 129 (11), 121 (12), 115 (10); exact mass found 336.1723, calcd for $C_{22}H_{24}O_3$ 336.17253; $[\alpha]^{25}_D = +49.5°$ ($c = 0.040$, $CHCl_3$).

(+)-*O*-Methyljoubertiamine (1). A flame-dried 1-mL reactivial under an N_2 atmosphere was charged with enone **15** (32.5 mg, 0.097 mmol) in CH_3CN (0.15 mL). Sodium iodide (72 mg, 0.48 mmol, 5 equiv) was added, and the reaction was heated for 10 s with a heat gun to dissolve the sodium iodide. The reactivial was cooled to room temperature, and chlorotrimethylsilane (0.06 mL, 0.481 mmol, 5 equiv) was added. The reaction was stirred for 1.75 h and then quenched with saturated aqueous sodium bisulfite solution (0.5 mL). The layers were separated, and the aqueous layer was extracted with ethyl acetate. All organic layers were combined, dried ($MgSO_4$), and concentrated under a stream of nitrogen. Dimethylamine (0.1 mL of a 40% aqueous solution of the amine) was added, and the solution was stirred for 30 min and then concentrated under a stream of nitrogen. The residual oil was concentrated in vacuo and chromatographed to give **1** (11.1 mg, 0.040 mmol, 42% yield based on **15**) as a yellow oil: R_f (ether/pH 10 buffer/diethylamine, 80:10:10) = 0.15. The ^{1}H NMR and MS data are identical with the literature values for synthetic[8b] and natural material,[8a] respectively. Because literature data for **1** is sketchy, full characterization is reported: ^{1}H NMR δ 7.20 (d, J = 8.9 Hz, 2 H), 7.12 (d, J = 10.3 Hz, 1 H), 6.87 (d, J = 8.9 Hz, 2 H), 6.14 (d, J = 10.2 Hz, 1 H), 3.79 (s, 3 H), 2.40–1.90 (m, 14 H); ^{13}C NMR δ 199.5 (u), 158.2 (u), 155.5 (d), 135.0 (u), 129.3 (d), 127.6 (d) × 2, 114.0 (d) × 2, 55.2 (d), 55.1 (u), 45.5 (d), 42.7 (u), 39.3 (u), 36.4 (u), 34.4 (u); IR 3386 (br), 2981, 2943, 1686, 1553, 1513, 1462, 1251, 1191, 1119, 1051; MS 273 (M^+) (22), 71 (13), 59 (10), 58 (100); exact mass found 273.1729, calcd for $C_{17}H_{23}NO_2$ 273.1729; $[\alpha]^{25}_D = +50.3°$ ($c = 0.003$, $CHCl_3$).

Acknowledgment. D.F.T. and J.F.M. thank the donors of the Petroleum Research Fund, administered by the American Chemical Society, for support of this research. J.F.M. wishes to thank Prof. E. Schweizer for helpful discussions during the course of this research.

Supplementary Material Available: Tables of bond distances and angles for the X-ray structure of **9** (3 pages). Ordering information is given on any current masthead page.

Stereochemistry of Reduction and Methylation of 5-(Trimethylsilyl)adamantan-2-one and 5-(Trimethylstannyl)adamantan-2-one[1]

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It is reported that the title compounds are reduced with sodium borohydride to give both the *E* and *Z* alcohols with the latter in small excess; the tin compound can also be treated with methyllithium to furnish the tertiary *E* and *Z* alcohols, with the latter again predominant. These findings lend further support to the conjecture that the stereochemistry of addition is controlled by transition-state hyperconjugation if steric and/or conformational factors are absent.

The reduction and alkylation of cyclohexanones are among the most thoroughly studied reactions of organic chemistry. One of the factors contributing to this development was Winstein's fruitful insight[2] that large groups such as phenyl and *tert*-butyl effectively lock cyclohexane rings in one of the two possible chair conformations; this feature enables chemists to study the question whether nucleophiles approach the carbonyl group of cyclohexanones preferably from the equatorial or the axial direction. The result, namely that attack from the more hindered axial side is strongly favored, drew much attention.[3] In time, it was realized that this preference must reflect an electronic factor, but while a number of proposals have been made, the nature of this factor remains controversial to this day.[4]

There is one problem associated with the use of locked cyclohexanones beside the fact that the two carbonyl faces

(1) This work was done by M.X. in partial fulfillment of the requirement for the M.S. degree.

(2) Winstein, S.; Holness, N. J. *J. Am. Chem. Soc.* **1955**, *77*, 5562.

(3) Dauben, W. G.; Fonken, G. J.; Noyce, D. S. *J. Am. Chem. Soc.* **1956**, *78*, 2579.

(4) For a summary of leading references, see: Mukerjee, D.; Wu, Y.-d.; Fronczek, F. R.; Houk, K. N. *J. Am. Chem. Soc.* **1988**, *110*, 3328.

0022-3263/89/1954-3836$01.50/0

Table I. ^{13}C Shift or Shift Differences of Compounds 2–5

	δ							
compd	$C_{1,3}$	C_2	$C_{4,9}$	C_5	C_6	C_7	$C_{8,10}$	Me
3	34.55	74.51	31.01	27.52	37.57	27.06	36.51	–
4	28.10	37.97	37.37	21.33	37.37	28.10	37.97	–5.48
5	28.40	37.79	37.79	28.40	37.79	28.40	37.79	–
E-2, calc	34.25	74.69	36.09	19.99	37.15	27.22	31.19	–5.48
Z-2, calc	34.25	74.69	30.59	20.45	37.15	26.76	36.34	–5.48
E-2, obs	34.04	74.70	36.45	19.95	37.00	26.98	30.94	–5.40
Z-2, obs	34.01	74.47	30.41	20.43	37.04	26.49	36.46	–5.58
E-2, $/\Delta^c/$	0.19	0.01	0.36	0.04	0.15	0.24	0.25	0.08
Z-2, $/\Delta^c/$	0.24	0.22	0.18	0.02	0.11	0.27	0.12	0.10
E-2, $/\Delta^i/$	0.19	0.01	5.86	0.50	0.15	0.22	5.40	0.08
Z-2, $/\Delta^i/$	0.24	0.22	5.68	0.44	0.11	0.73	5.27	0.10

Figure 1. The incipient σ* orbital of the C–Nu bond, and delocalization of antiperiplanar σ bonds.

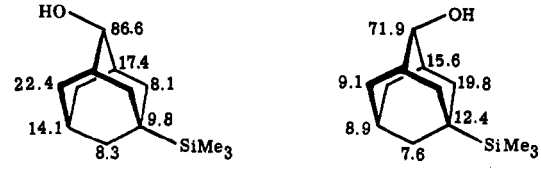
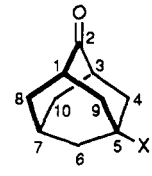


Figure 2. The slopes of the carbon signals of the 5-(trimethylsilyl)adamantan-2-ols vs the concentration of $Eu(fod)_3$, based on six measurements; the correlation coefficients were in all cases more than 0.990, and average 0.998.

are sterically inequivalent: the absence of any directing effects of the locking groups themselves has only been *assumed*. The simultaneous presence of these two caveats made it impossible to weigh the importance of either one, until we began using 5-substituted adamantan-2-ones 1-X as a probe in these reactions.[5]



1-X

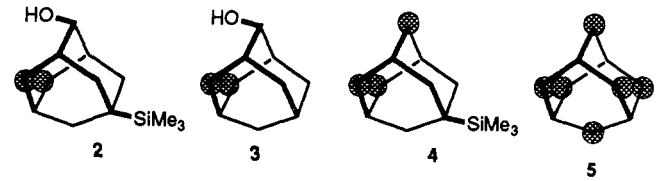
With this probe, we learned that the *tert*-butyl group is indeed innocent of any directive effect in reduction unless the reducing agent is itself an exceedingly bulky one: anti approach to give a small excess of *Z* alcohol may then be observed. With common reducing agents such as sodium borohydride, a 50/50 mixture of alcohols was obtained. However, when acceptor groups such as phenyl, halogen, or hydroxy were used as the 5-substituent, pronounced directive effects were observed: *E* alcohols were obtained in excess (usually two or three to one) in every case. *Z* alcohols were obtained in excess only with 5-phenyl groups carrying an electron-donating para substituent such as amino. We explained our data in terms of transition state hyperconjugation, a notion advanced by Cieplak in 1981 to explain the contrasteric reduction of cyclohexanones.[6] In that paper, the argument is made that antiperiplanar C–H bonds are better donors than C–C bonds. The difference between the faces vanishes in adamantanone; the function of 5-substituent is to differentiate the vicinal flanking carbon–carbon bonds (see Figure 1). The electron-richer bonds then direct the nucleophile to the antiperiplanar position so as to allow σ delocalization into the incipient (and in the transition state: still low-energy) σ* orbital. In view of the absence of data with electropositive substituents, we felt it would be worth while to examine such stereochemistry as might be induced by the σ donors, trimethylsilyl and trimethylstannyl.

(5) Cheung, C. K.; Tseng, L. T.; Lin, M.-h.; Srivastava, S.; le Noble, W. J. *J. Am. Chem. Soc.* **1986**, *108*, 1598.
(6) Cieplak, A. S. *J. Am. Chem. Soc.* **1981**, *103*, 4540.

Results and Discussion

The two ketones were prepared[7] from the readily available bromide 1-Br by protection of the carbonyl group as the ethylene ketal, anionic coupling, and deprotection. The latter reaction seemed somewhat risky in view of the well-known propensity of carbon–tin bonds to undergo protiodestannylation, but we found conditions that left this bond intact.

The reduction of 1-$SiMe_3$ was carried out at room temperature in 2-propanol solution; the yield was quantitative. Analysis of the C_2 signals in the ^{13}C NMR spectrum of the mixture indicated a product ratio of 55 to 45, and indeed chromatographic separation gave the two alcohols in a 55 to 45 weight ratio. The assignment of configuration was based on the ^{13}C NMR additivity method, which is very reliable for rigid structures.[8] The carbon atoms are counted as in 1-X, and the chemical shift of each carbon atom of, say, the *E* isomer, is calculated according to $\delta_{E\text{-}2} = \delta_3 + \delta_4 - \delta_5$. In cases where the ^{13}C signals have not been



2 3 4 5

previously determined, they can be assigned with help of the standard devices of attached proton tests, carbon–hydrogen correlation, paramagnetic shift reagents, C–X couplings, and so on. The data for the case at hand are shown in Table I. The symbols $/\Delta^c/$ and $/\Delta^i/$ are simply the absolute differences between the calculated and observed values when the correct vs the incorrect sets are compared. The data for compounds **3–5** can be found in the literature.[8-10]

For the carbons in the carbonyl plane ($C_{1\text{-}3,6}$), the calculated values are the same, and the differences between

(7) We are indebted to Professor Cyril Grob (Basel) for details; see the Experimental Section.
(8) Srivastava, S.; Cheung, C. K.; le Noble, W. J. *Magn. Reson. Chem.* **1985**, *23*, 232.
(9) Pai, Y.-m.; Wanek, E.; Weber, W. D. *J. Organomet. Chem.* **1984**, *270*, 271.
(10) Della, E. W.; Patney, H. K. *Aust. J. Chem.* **1979**, *32*, 2243.

Table II. Product Distribution in the Reduction of Ketone 1-X

X	Nu	solvent	t, °C	% E	% Z	anal.	ref
CMe_3	$LiAlH_4$	ether	rt	50	50	HPLC	5
CMe_3	$LiAl(O\text{-}t\text{-}Bu)_3H$	ether	rt	42	58	HPLC	5
$SiMe_3$	$NaBH_4$	$i\text{-}C_3H_7OH$	rt	45	55	^{13}C NMR	*a*
$SiMe_3$	$NaBH_4$	$i\text{-}C_3H_7OH$	rt	45	55	weight	*a*
$SnMe_3$	$NaBH_4$	$i\text{-}C_3H_7OH$	rt	43.5	56.5	^1H NMR	*a*
$SnMe_3$	MeLi	ether	0	36.5	63.5	^1H NMR	*a*
$SnMe_3$	MeLi	ether	0	35.5	64.5	^{13}C NMR	*a*
F	$NaBH_4$	$i\text{-}C_3H_7OH$	rt	62	38	^1H NMR	5
F	MeLi	ether	0	70	30	GC	5

[a] This work.

correct and incorrect give only a rough measure of how small these differences can be expected to be. The average deviation ($C_{1,3}$ counted twice) is 0.17 ppm. The good fit of $C_{4,8\text{-}10}$ (av 0.18 ppm) when the correct choice is made vs the fit that results from the incorrect option (av 5.56 ppm) is especially revealing, but even the smaller differences for C_5 and C_7 (averages 0.14 and 0.47 ppm) point in the same direction.

The assignment was further confirmed by means of a study of the effect of the paramagnetic shift reagent Eu(fod)$_3$ on the carbon signals in both epimeric alcohols. From the effects of the relative concentrations of alcohol and reagent, slopes were calculated for each carbon; the values (in arbitrary units) are given in Figure 2. The relation between the slopes and the distance of the carbons to the hydroxy function is at once obvious.

The reduction and methylation of the tin compound followed similar lines. The results are shown in Table II, together with a few earlier results for comparison.

The data show that the preferred direction is indeed the opposite of that shown with electronegative elements; they further support the view previously expounded that the hyperconjugative model of Figure 1 is suitable for the prediction of the stereochemistry encountered in addition reactions of trigonal carbon. As in most of our previous work, the deviations of the product ratios from unity are modest; this is the price that must be paid for locating the electronically perturbing substituent far enough away from the reacting center to ensure that it is sterically innocuous. The ability of the methylation reaction to differentiate somewhat more than hydride reduction[11] was observed once again in this research.

Experimental Section

Mass spectra were determined on a Hewlett-Packard 5980-A spectrometer. Molecular ion peaks of the organotin compounds are given for the ^{120}Sn isotope. ^1H and ^{13}C NMR spectra were recorded with a QE-300 spectrometer. IR spectra were measured with a Perkin-Elmer Model 1430 or Model 1600 spectrometer; all samples were studied in the form of KBr disks. Microanalyses were done by Galbraith Laboratories.

5-Bromoadamantan-2-one Ethylene Ketal (6). 5-Bromoadamantan-2-one (775 mg), ethylene glycol (400 mg), and a catalytic amount of *p*-toluenesulfonic acid were dissolved in 30 mL of benzene. After refluxing for 8 h in a Dean–Stark apparatus containing anhydrous calcium chloride (5 g) to trap the water formed, the solution was cooled and washed with 10% aqueous sodium carbonate (20 mL), water (30 mL), and saturated aqueous sodium chloride (30 mL). The organic solution was dried over anhydrous magnesium sulfate, filtered, and evaporated to dryness to give **6** as white needles (905 mg, 98%). ^1H NMR ($CDCl_3$): δ 3.90 (s, 4 H), 2.75–1.50 (m, 13 H).

5-(Trimethylsilyl)adamantan-2-one Ethylene Ketal (7). A solution of hexamethyldisilane (6.0 mL) in anhydrous HMPA (2.0 mL) was cooled under nitrogen to 0 °C. Ethereal methyllithium (3.2 mL, 4.8 mmol) was added by syringe, and the resulting deep-red solution was stirred for 15 min to complete the preparation of (trimethylsilyl)lithium. The solution was chilled to −78 °C and a solution of **6** (250 mg, 0.90 mmol) in 3.0 mL of anhydrous ether was added during 1 min; the temperature rose to 10 °C. The mixture was poured into pentane (10 mL) and thoroughly washed with water (3 × 25 mL) to remove HMPA. Drying ($MgSO_4$) and solvent removal gave 220 mg of crude **7**. Kugelrohr distillation (0.5 mmHg, 50 °C) was used to remove most of the side product (adamantanone ethylene ketal); further purification by flash chromatography (2.5% ethyl acetate in hexane) gave **7** (70.0 mg, 29%). ^1H NMR ($CDCl_3$): δ 3.93 (s, 4 H), 2.03–1.55 (m, 13 H), −0.105 (s, 9 H). ^{13}C NMR ($CDCl_3$): δ 111.44, 64.17, 64.06, 36.52, 35.90, 34.77, 26.38, 19.76, −5.34.

5-(Trimethylsilyl)adamantan-2-one (1-SiMe$_3$). A solution of compound **7** (70 mg) in a mixture of methanol (12 mL) and 1 M aqueous HCl (2 mL) was refluxed for 15 min, cooled, and extracted with methylene chloride (20 mL × 3). The organic layer was washed with 10 mL of 10% aqueous sodium carbonate and dried with magnesium sulfate. Flash evaporation gave the title compound (58 mg, 99%); mp 68–71 °C. MS (m/z): 223 (M + 1, 2.6), 222 (M, 12.1), 73 ($SiMe_3$, 100). IR (cm^{-1}): 2910 (s), 1700 (s), 1240 (s), 858 (m), 827 (s). ^1H NMR ($CDCl_3$): δ 2.52–1.80 (m, 13 H), −0.08 (s, 9 H). ^{13}C NMR ($CDCl_3$): δ 218.81, 46.74, 40.05, 38.99, 36.01, 26.88, 21.45, −5.31.

5-(Trimethylsilyl)adamantan-2-ols (2). Ketone 1-SiMe$_3$ (80 mg, 0.36 mmol), dissolved in 2.5 mL of 2-propanol, was treated with 40 mg of sodium borohydride. The reaction mixture was stirred for 3 h at room temperature, washed with saturated aqueous ammonium chloride, and extracted with ethyl ether (3 × 15 mL). Further workup produced **2** in quantitative yield (80.3 mg). ^{13}C NMR revealed a C_2 peak ratio of 45/55. The isomers were separated with flash chromatography (hexane/ethyl acetate = 8/2) to give *Z*-**2** (37 mg, R_f = 0.65) and *E*-**2** (30 mg, R_f = 0.59). *Z*-2: mp 117–118 °C. MS (m/z): 224 (M, 1.6), 73 ($SiMe_3$, 100). IR (cm^{-1}): 3300 (m), 2890 (s), 1240 (s), 1025 (s), 858 (s), 830 (s). ^1H NMR ($CDCl_3$): δ 3.89 (s, 1 H), 2.11–1.40 (m, 14 H), −0.10 (s, 9 H). ^{13}C NMR, see Table I. *E*-2: mp 143–145 °C. MS (m/z): 225 (M + 1, 1.8), 224 (M, 12.5), 73 ($SiMe_3$, 100); IR (cm^{-1}): 3300 (m), 2890 (s), 1240 (s), 1025 (s), 858 (s); ^1H NMR ($CDCl_3$): δ 3.82 (s, 1 H), 2.17–1.55 (m, 14 H), −0.10 (s, 9 H). ^{13}C NMR, see Table I.

5-(Trimethylstannyl)adamantan-2-one Ethylene Ketal (8). A solution of 100.0 mg (0.50 mmol) of trimethyltin chloride in tetrahydrofuran (6 mL) was added to a stirred, cooled suspension of lithium chips (35 mg) in anhydrous tetrahydrofuran (8 mL) slowly enough to maintain the temperature below 5 °C. After completion of the addition, the mixture was dark green. Stirring was continued for 4 h; then the mixture was transferred via syringe into a cooled solution of **6** (90 mg, 0.33 mmol) in tetrahydrofuran (5 mL) at a rate such that the temperature was maintained at 0 °C. The mixture was allowed to warm to room temperature, and stirring was continued for 15 h; saturated aqueous ammonium chloride solution was added, the mixture was extracted with petroleum ether (3 × 50 mL), and the combined extract was dried ($MgSO_4$) and reduced to small volume. Flash chromatography (90% CH_2Cl_2 and 10% of hexane) gave pure **8** (91.8 mg, 78%). ^1H NMR ($CDCl_3$): δ 3.94 (s, 4 H), 2.13–1.73 (m, 13 H), −0.04 (s, 9 H). ^{13}C NMR ($CDCl_3$): δ 111.34, 64.20, 64.06, 41.58, 39.35, 37.30, 34.95, 27.75, 26.04, −12.80.

5-(Trimethylstannyl)adamantan-2-one (1-SnMe$_3$). The procedure used was similar to that described for the silyl analogue;

(11) Lin, M.-h.; Silver, J. E.; le Noble, W. J. *J. Org. Chem.* **1988**, *53*, 5155.

31.5 mg product was obtained from 36.0 mg of **8**. Mp: 81–82 °C. MS (m/z): 316 (M + 2, 5.3), 315 (M + 1, 44.0), 299 (M – CH_3, 53.1), 165 ($SnMe_3$, 100.0). IR (cm^{-1}): 2909 (s), 2839 (w), 1712 (s), 766 (m), 526 (s), 464 (w). ^1H NMR ($CDCl_3$): δ 2.55–1.94 (b m, 13 H), –0.005 (s, 9 H). ^{13}C NMR ($CDCl_3$): δ 218.1, 48.33, 44.36, 40.66, 39.04, 28.07, 26.79, –12.67. Anal. Calcd for $C_{13}H_{22}OSn$: C, 49.90; H, 7.09. Found: C, 50.12; H, 7.20.

5-(Trimethylstannyl)adamatan-2-ol (9). The procedure used was similar to that described for **2**; 70 mg of **9** was obtained in quantitative yield. After flash chromatography, we obtained *Z*-**9**, mp 109 °C. MS (m/z): 316 (M, 0.7), 151 (M – $SnMe_3$, 57), 165 ($SnMe_3$, 43). IR (cm^{-1}): 1446 (w), 1057 (m), 1027 (w), 766 (s), 522 (s), 510 (w). ^1H NMR ($CDCl_3$): δ 3.91 (b, 1 H), 2.27–1.70 (m, 14 H), –0.048 (s, 9 H). ^{13}C NMR ($CDCl_3$): δ 74.64, 41.99, 36.57, 35.27, 27.80, 27.03, –13.05. Anal. Calcd for $C_{13}H_{24}OSn$: C, 49.56; H, 7.68. Found: C, 49.71; H, 7.74. *E*-**9**: mp 138–140 °C. ^1H NMR ($CDCl_3$): δ 3.87 (b, 1 H), 2.17–1.25 (m, 14 H), –0.036 (s, 9 H). ^{13}C NMR ($CDCl_3$): δ 74.54, 41.93, 40.98, 35.33, 31.07, 28.34, 26.22, –12.95. Anal. Calcd for $C_{13}H_{24}OSn$: C, 49.56; H, 7.68. Found: C, 49.39; H, 7.83.

2-Methyl-5-(trimethylstannyl)adamantan-2-ol (10). An ethyl ether solution of methyllithium (1.5 M, 1 mL) was injected slowly into a solution of 1-$SnMe_3$ (106 mg, 0.34 mmol) in 5 mL of anhydrous ether at 0 °C. The mixture was allowed to react for 3 h at 0 °C, quenched with saturated aqueous ammonium chloride, and extracted with ether (3 × 50 mL). The combined extract was washed with saturated aqueous sodium chloride, dried ($MgSO_4$), and evaporated, giving a mixture of the isomers of **10** in quantitative yield. They were separated by flash chromatography (85% hexane, 15% ethyl acetate). *Z*-**10**: mp 83 °C. MS (m/z): high resolution, 330.1006 (calcd 330.1006); 330 (M, 4.1), 165 ($SnMe_3$, M – $SnMe_3$, 100). IR (cm^{-1}): 3356 (m), 2884 (s), 1121 (m), 920 (w), 761 (w), 522 (m). ^1H NMR ($CDCl_3$): δ 2.37–2.33 (d, b, 2 H), 1.92–1.64 (m, b, 11 H), 1.39 (s, 1 H), 1.33 (s, 3 H), –0.04 (s, 9 H). ^{13}C NMR δ 73.81, 42.72, 39.88, 37.25, 35.17, 28.32, 27.66, 26.29, –12.94. *E*-**10**: mp 93 °C. ^1H NMR: δ 2.22–2.19 (d, b, 2 H), 2.01–1.59 (m, b, 11 H), 1.51 (s, 1 H), 1.32 (s, 3 H), –0.04 (s, 9 H). ^{13}C NMR: δ 73.65, 42.63, 39.84, 39.51, 33.00, 27.85, 27.21, 26.51, –13.01.

Shift Reagent Studies. $Eu(fod)_3$ was dried in a vacuum Büchi GKR-50 desiccator over P_2O_5 for 12 h. $CDCl_3$, which was stored over activated molecular sieves (4A), was used to dissolve the $Eu(fod)_3$ and the alcohols. Typically, 0.5 mL of 0.8 M alcohol solution and 0.3 mL of 0.2 M $Eu(fod)_3$ solution were prepared separately. ^{13}C NMR spectra were measured in the presence of varying amounts of the shift reagent solution: 0.015, 0.030, 0.045, 0.060, 0.075, and 0.090 mL. The assignment was based on the fact that the carbon atoms on the syn side of hydroxy group are shifted downfield more than the carbon atoms on the anti side.

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Effects of Two Oppositely Polarizing, Distant Substituents on the Rate and Stereochemistry of Solvolysis of 2-Adamantyl Tosylate[1]

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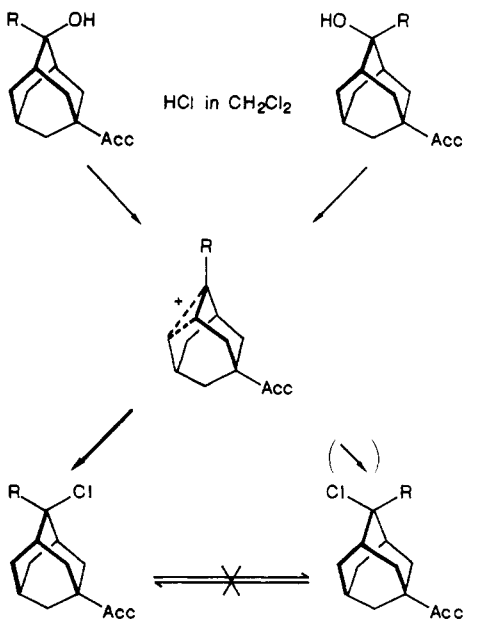
The hydrolysis rates are reported of (*E*)- and (*Z*)-5-fluoro- and -(trimethylstannyl)adamant-2-yl tosylate as well as of the parent ester. The fluoro derivatives react 4–6 orders of magnitude more slowly than the parent, while the tin compounds do so about the 10 times more rapidly. The (*Z*)-fluoro ester and the (*E*)-tin ester react with complete retention; the (*E*)-fluoro ester and (*Z*)-tin compound undergo significant inversion. The epimeric rate ratios (*E*/*Z*) are about 0.005 for the fluoro pair and 0.7 for the tin pair.

In 1970, the Schleyer group reported[2–4] solvolysis rates for 2-adamantyl esters under a variety of conditions and drew the conclusion that these reactions were remarkably free of solvent assistance and neighboring-group participation.[5] These results proved to be very stimulating, and 2-adamantyl solvolysis became a durable mainstay among the physical organic chemist's interests. In the subsequent literature, an important place must be accorded to a paper by Whiting[6] in which it was shown that if a 5-methyl group is present, both secondary and tertiary derivatives of 2-adamantanol hydrolyze to give primarily the alcohols from which they were derived, i.e., with retention of configuration. Another landmark paper was that by Bunnett,[7] who showed that ion pairing must be an important feature

Scheme I



of the reaction since oxygen scrambling occurs in the tosylate during solvolysis. The interest in the adamantyl

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