Table I. Stereospecificities in Pyrolytic 1,3-Sigmatropic Rearrangements

Reactant	R	X	n	Rate ratio (sr/si)	Ref
		Unblocked			
1	*exo*-OAc			Low[b]	*c*
1	*exo*-Me			0.005	*d*
2	*exo*-D	OAc	1	0.053	4a, 5
2	*exo*-Me	OAc	1	0.1	4b, 5
2	*exo*-Me	$OSiMe_3$	2	0.42	*a*
2	*exo*-Me	OAc	2	0.45	*a*
3	*trans*-C_3H_5			0.85	*e*
3	*cis*-C_3H_5			0.97	*e*
		Blocked			
1	*endo*-Me			0.45	*d*
2	*endo*-Me	OAc	1	7	4b, 5
2	*endo*-Me	OAc	2	12	*a*
2	*endo*-Me	$OSiMe_3$	2	15	*a*

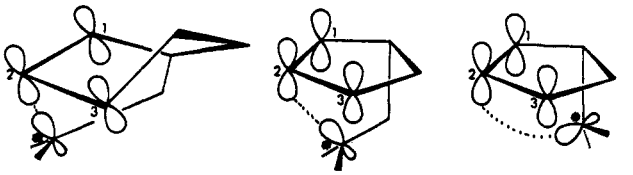
[a] This work. [b] Only the si product was reported. [c] S. Masamune, N. Nakatsuka, R. Vukov, and E. N. Cain, *J. Amer. Chem. Soc.*, **91**, 4322 (1969). [d] W. R. Roth and A. Friedrich, *Tetrahedron Lett.*, 2607 (1969). [e] J. A. Berson and P. B. Dervan, *J. Amer. Chem. Soc.*, **95**, 269 (1973).

of 7-*exo*-methylbicyclo[3.2.0]hept-2-en-6-*endo*-yl acetate (**2**, n = 1, R = *exo*-Me, X = OAc) is greater than the rate of rearrangement with retention (k_{ret}) from the *endo*-methyl analog (**2**, n = 1, R = *endo*-Me, X = OAc), as might be expected if the *exo*-methyl compound but not the *endo*-methyl one were rearranging concertedly. However, the rate factor is only 7, hardly an impressive driving force. Also, the stereospecificities, factors of 10 favoring inversion in the *exo*-methyl isomer and 7 favoring retention in the *endo*-methyl compound, provide little support for a sharp discontinuity in mechanism.

In the bicyclo[4.2.0]octenyl series, the absolute rate, k_{ret}, from **2** (n = 2, R = *endo*-Me, X = $OSiMe_3$) is actually greater than k_{inv} from the *exo*-methyl counterpart **2** (n = 2, R = *exo*-Me, X = $OSiMe_3$), the ratio being about 3.1 at 320°. Moreover, the preferences for retention in both *endo*-methyl compounds (**2**, n = 2, R = *endo*-Me, X = OAc or $OSiMe_3$), factors of 12 and 15, respectively, also are greater than the preferences for inversion in the *exo*-methyl counterparts (factors of 2.2 and 2.4, respectively, for **2**, n = 2, R = *exo*-Me, X = OAc or $OSiMe_3$). Thus, in these cases, a concerted mechanism seems to fit the experimental facts for the formally forbidden reaction at least as well as for the allowed one.

Table I also reveals a strong dependence of the sr/si ratio on reactant structure. In both the "unblocked" and "blocked" series, the forbidden sr reaction steadily increases in relative importance as the reactant changes in the order bicyclo[2.1.1]hexenyl (**1**) < bicyclo[3.2.0]-heptenyl (**2**, n = 1) < bicyclo[4.2.0]octenyl (**2**, n = 2) < monocyclic (**3**).

The hypothesis that both the allowed inversion and forbidden retention reactions are concerted permits a straightforward analysis of the ordering of the sr/si ratios. As has been emphasized elsewhere,[6] overlap between the front lobe of the migrating carbon and the suprafacial lobe of C_2 of the allylic framework strongly stabilizes the transition state of the forbidden concerted sr pathway. This overlap should be very sensitive to geometric factors. Molecular models clearly show that the greater flexibility introduced by the extra methylene group of the bicyclo[4.2.0]octenyl reactants makes possible a conformation and an sr transition state derived from it (**10**) in which overlap of the relevant orbital



10 11 12

lobes at C_2 and the migrating carbon (C*) is more favorable than in the corresponding transition states from the rigid bicyclo[3.2.0]heptenyl reactants (**11**), and much more favorable than in the bicyclo[2.1.1]-hexenyl cases (**12**). The monocyclic cases (**3**) should permit optimum overlap of this type, in agreement with the observation that in the unblocked series they show the highest sr/si ratio (Table I).

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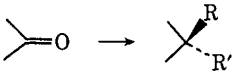
New Synthetic Reactions. Geminal Alkylation

Sir:

The creation of a fully substituted carbon center with controlled stereochemistry presents a general yet unsolved problem in organic synthesis. The ready availability of the carbonyl group makes it highly desirable to be able to convert a carbonyl carbon to a quaternary center as represented by eq 1. Two recent



(1)

approaches involve the use of the thio-Claisen rearrangement[1] and organolithium addition to ketene thioacetals.[2] We wish to report a new approach to this problem based upon the spiro annelation procedure.[3]

We have previously reported the facile synthesis of cyclobutanones from carbonyl partners by the condensation with diphenylsulfonium cyclopropylide.[3] This reaction proceeds with a high degree of stereoselectivity. Thus, treatment of 4-*tert*-butylcyclohexanone with this sulfur ylide followed by rearrangement of the intermediate oxaspiropentane with $Eu(fod)_3$ produced only the spiro cyclobutanone **1** uncontaminated by its isomer.[4,5] Similarly, the spiro cyclobu-

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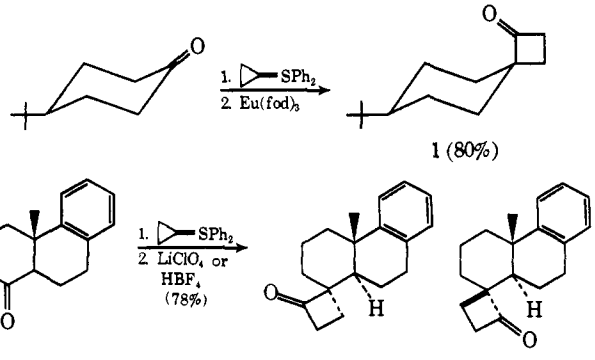
(2) P. F. Jones and M. F. Lappert, *J. Chem. Soc., Chem. Commun.*, 526 (1972); F. A. Carey and A. S. Court, *J. Org. Chem.*, **37**, 1926 (1972); D. Seebach, B. T. Gröbel, A. K. Beck, M. Braun, and K. H. Geiss, *Angew. Chem., Int. Ed. Engl.*, **11**, 443 (1972); D. Seebach, *Synthesis*, **1**, 17 (1969).
(3) B. M. Trost and M. J. Bogdanowicz, *J. Amer. Chem. Soc.*, **93**, 3773 (1971); M. J. Bogdanowicz and B. M. Trost, *Tetrahedron Lett.*, 887 (1972).
(4) Proof of stereochemistry was based upon conversion to a γ-butyrolactone with hydrogen peroxide and subsequent reduction to a tetrahydrofuran. The latter was synthesized independently; see M. J. Bogdanowicz and B. M. Trost, *Tetrahedron Lett.*, in press.
(5) All new compounds have satisfactory analytical and spectroscopic data to support the assignments.

tanone **2** was the unique product of the reaction of the respective tricyclic ketone with the cyclopropylide utilizing lithium perchlorate as the rearranging agent of the intermediate oxaspiropentane. In this case the structural assignment rests with the unusual solvent and europium(+3) shifts for the angular methyl group.[5] Thus, the absorption for this methyl shifts from 74.5 to 81.0 Hz (at 60 Mc) in switching from carbon tetrachloride to benzene solvent; whereas, in the alternative isomer **3**, the normal upfield shift from 83.0 to 72.0 Hz for the same solvent change is exhibited. The deshielding of the methyl group in **2** is in accord with this group lying in front of the plane perpendicular to the plane of the carbonyl group and bisecting the carbonyl bond.[6] Furthermore, this group shows a shift of 108 Hz compared to 185 Hz for the methylene group α to the carbonyl upon addition of $Eu(fod)_3$ confirming the close proximity of the carbonyl group and the angular methyl.

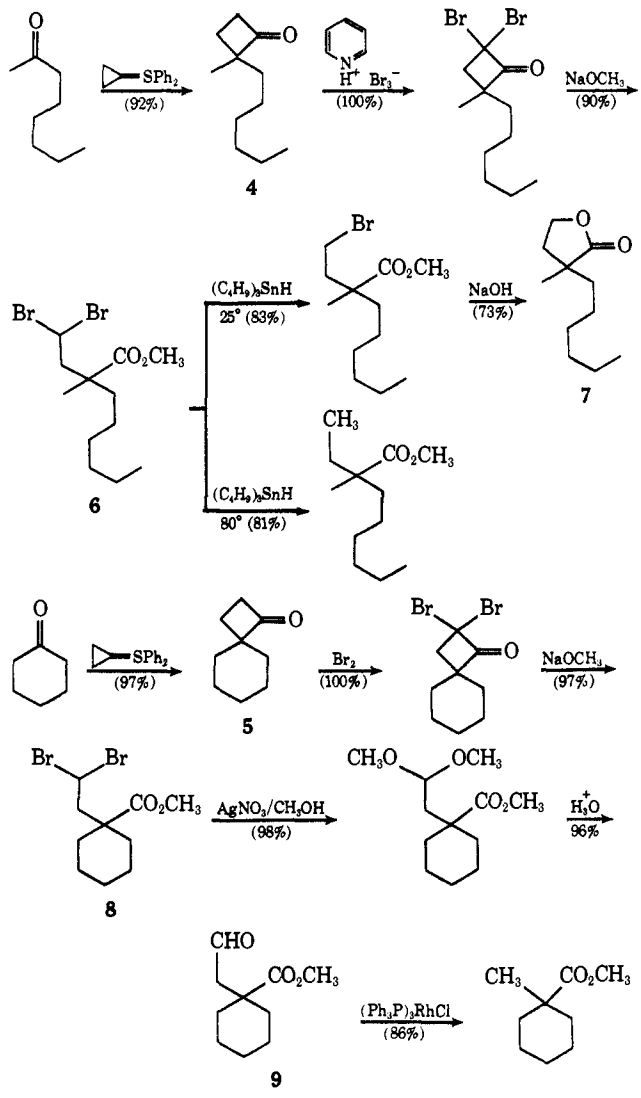


	2	3
$LiClO_4$	100	—
HBF_4	93	7

With the demonstration of the high stereoselectivity for the spiro annelation, attention was directed toward modification of the cyclobutanone into two carbon chains differentially functionalized. Bromination of cyclobutanones **4** and **5** with molecular bromine in carbon tetrachloride at room temperature or preferably with pyridinium bromide perbromide in glacial acetic acid effected quantitative conversion to the α,α-dibromo ketones (see Scheme I).[5] Dissolution in methanolic sodium methoxide initiates virtually instant cleavage of the ring.[5,7] The dibromoethyl chain provides a versatile structural unit. Thus treatment of γ,γ-dibromo ester **6** with tri-*n*-butyltin hydride at room temperature effects monodehalogenation which upon base hydrolysis of the ester and subsequent acidification affords the lactone **7**;[5] whereas, treatment with the tin hydride at 80° yields the ethyl group.[5]

Alternatively, the *gem*-dibromo group represents a masked carbonyl. For example, treatment of the γ,γ-dibromo ester **8** derived from cyclobutanone **5** with methanolic silver nitrate replaces both bromines with methoxy groups and subsequently with hydrochloric acid in aqueous dioxane completes, the unmasking of the carbonyl group to generate the succinaldehydic ester **9**.[5] The versatility of the aldehyde and the ester functional groups allows easy selective

Scheme I. Geminal Alkylation



reactions at either chain. To provide one illustration of this point, Wilkinson's catalyst provides smooth decarbonylation of the aldehyde to create a methyl group.[5,8,9] The facile conversion of a carbonyl group to an α-methyl carboxylic acid unit has many applications in natural product synthesis.

The method outlined achieves a facile conversion of a carbonyl group into two alkyl chains at different oxidation levels and thus with great flexibility to modify either chain selectively. Although the number of steps may seem objectionable, each step proceeds rapidly and in high yield. Thus, the isolated yield of the succinaldehydic ester **9** from cyclohexanone is 89% and of lactone **7** from 2-octanone is 50% even though no attempt was made to maximize yields. The use of other nucleophiles—be they heteroatomic groups or organometallics—to effect the ring cleavage expands the scope of the method to fulfill the generality of the approach.

Acknowledgment. We express our thanks to the National Science Foundation and the National Insti-

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tutes of Health for their generous support of our program.

(10) Camille and Henry Dreyfus Teacher-Scholar Grant Recipient.

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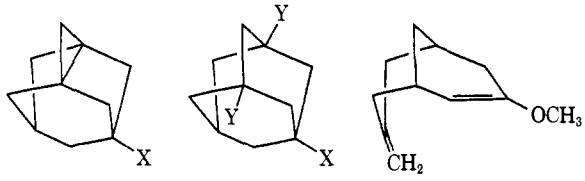
Compounds Containing Inverted Carbon Atoms. Synthesis and Reactions of Some 5-Substituted 1,3-Dehydroadamantanes

Sir:

Small ring propellanes[1] and polycyclic compounds containing "inverted carbon"[2,3] atoms present interesting theoretical questions with regard to hybridization, p-σ bonding, and strain energies.[3-6] The few known examples of inverted carbon compounds show that they possess unusual chemical reactivity; *e.g.*, [3.2.1]propellane[3,7] and 1,3-dehydroadamantane[8,9] react spontaneously with oxygen in solution at room temperature. We present here the synthesis and some reactions of 5-substituted 1,3-dehydroadamantanes (**1**) together with some thermochemical data bearing on



1 2 3

strain energy. These compounds, derivatives of [3.3.1]propellane, are now the most accessible type of inverted carbon compound.

1,3,5-Tribromoadamantane (**2**, X = Y = Br)[10] reacts with *n*-butyllithium at −35° in ether containing hexamethylphosphoramide (25:1 v/v) to give 1,3-dehydro-5-bromoadamantane (**1**, X = Br). Unlike the known[9] unsubstituted compound **1** (X = H), which is readily isolated by glpc or by sublimation from a similar reaction of 1,3-dibromoadamantane with *n*-butyllithium–HMPA, the high reactivity of the bromo derivative has prevented its isolation. However, the presence of **1** (X = Br) was shown, after removal of ether solvent below 0°, by treatment with iodine in pentane to yield 1,3-diiodo-5-bromoadamantane (**2**, X = Br, Y = I), mp 113.5–114°, δ (benzene) 2.95 ($ICCH_2CI$, s), 2.87 (two of $ICCH_2CBr$, s), 1.92 (two of $ICCH_2C$, d, J = 3 Hz), 1.82 ($BrCCH_2C$, d, J = 3 Hz), and 1.15 (bridgehead H, m). *Anal.* Calcd for $C_{10}H_{13}BrI_2$: C, 25.69; H, 2.78; Br, 17.13; I, 54.39. Found: C, 25.97; H, 2.88; Br; 17.00; I; 54.18.

Unusual reactivity for bromide substitution and a driving force for subsequent ring opening in **1** (X = Br) is shown by its rapid hydrolysis between −35° and room temperature to yield 7-methylenebicyclo[3.3.1]-nonan-3-one. Initial substitution by hydroxyl is followed by a fragmentation of the 2-hydroxy-1-cyclopropyl moiety of **1** (X = OH) to give this known[11] methylene ketone. Similar ring opening occurs even when X is methoxyl since addition of methanol to a solution of bromide yields the methyl vinyl ether **3**, δ (benzene) 4.95 (CH_2=C, s), 4.8 (other CH_2=C, s), 4.65 (OC=CH, d, J = 6 Hz), 3.4 (OCH_3, s), and 2.7–1.6 (complex multiplets). *Anal.* Calcd for $C_{11}H_{16}O$: C, 80.44; H, 9.82. Found: C, 80.47; H, 9.91. However, after initial reaction of the bromide **1** (X = Br) with methanol in diethyl ether at −35°, the unstable methyl ether (**1**, X = OCH_3) may be trapped at −20° by addition of iodine to produce (*R*,*S*)-1-iodo-3-ethoxy-5-methoxyadamantane,[12] separated by glpc, δ (CCl_4) 3.43 and 1.1 (q and t of ethoxyl group), 3.20 (CH_3O, s), 2.42 (two of $ICCH_2CO$–, s), 2.3 (three H's of a CH_2 bridge and CH bridgehead), 1.69 (three other CH_2 units, broad s). *Anal.* Calcd for $C_{13}H_{21}O_2I$: C, 46.43; H, 6.25; I, 37.80. Found: C, 46.19; H, 6.39; I, 37.56.

An isolable derivative of the 1,3-dehydroadamantane system is produced when the group X in structure **1** has neither electron donor nor solvolytic capabilities. Reaction of a solution of **1** (X = Br) with sodium cyanide in hexamethylphosphoramide at −35 to 20° over 3 hr gave 5-cyano-1,3-dehydroadamantane[13] (**1**, X = CN) separated by sublimation and glpc, δ (benzene) 2.45 (bridgehead H, broad s), 1.45–2.05 (eight hydrogens, complex multiplets), and two pairs of doublets at 1.35 and 0.85 (two of CH_2CCN, J_{ab} = 11 Hz). *Anal.* Calcd for $C_{11}H_{13}N$: C, 82.97; H, 8.23; N, 8.80. Found: C, 82.88; H, 8.44; N, 8.63. An X-ray structural determination[15] of this solid compound shows that the two bridgehead carbon atoms of the cyclopropyl ring are "inverted"; *i.e.*, that all attached atoms lie within a hemisphere around each bridgehead carbon atom. These carbon atoms are 0.1 Å above the plane of the three attached methylene carbon atoms and the 1,3-cyclopropyl carbon–carbon bond length is a remarkably long 1.64 Å.[16] High σ bonded p character of the central cyclopropyl bond in **1** is apparent from this bond length.

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(11) H. Stetter and P. Tacke, *ibid.*, **96**, 694 (1963).
(12) The ethoxyl group is derived from diethyl ether solvent. Similar reactions are reported for ring openings of [3.2.1]propellane[3] and 1,3-dehydroadamantane.[9]
(13) This ready exchange of bromide by cyanide in dehydroadamantane (**1**) may be contrasted with the preparation of 1-cyanoadamantane by reaction of 1-bromoadamantane with sodium cyanide in pyridine where temperatures up to 230° are used for the exchange.[14] A homoconjugative effect of the p orbitals in the 1,3-bond of dehydroadamantanes toward the five position in **1** (X = Br) is apparent from the fast rates of hydrolysis, methanolysis, and cyanide exchange; see R. M. Coates and J. L. Kirkpatrick, *J. Amer. Chem. Soc.*, **92**, 4883 (1970), and references therein.
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