ester 9. Stereoselective carbometalation of acetylenic ester 9 with lithium dimethylcuprate followed by $LiAlH_4$ reduction of the resulting Z trisubstituted ester affords the allylic alcohol 10 in good yield. Conversion of alcohol 10 to unstable bromide 11[10] is straightforward. Alkylation of the dianion derived from 3-methyl-3-buten-1-ol with bromide 11 by a modification of the procedure of Cardillo et al.[13] then provides the desired diene 12 in 30% overall yield from alcohol 6.

The oxidative cyclization of diene 12 to a THF derivative of type 4 was accomplished in two ways. Thus, as shown in Scheme III, protection of the primary hydroxyl grouping of diene 12 gives the benzyl ether 13. Oxidation with potassium permanganate in buffered aqueous acetone gives stereospecifically the THF diol 14 in 46% yield at 70% conversion (33% isolated yield of pure 14 and 30% recovered starting material after flash chromatography). An alternative route to THF diol 14 utilizing the Cr(VI) promoted oxidative cyclization of 5,6-dihydroxyalkenes[8c] was also explored. Thus, VO(acac)-promoted oxidation of the homoallylic alcohol moiety of diene 12,[14] followed by protection of the hydroxyl grouping as the benzyl ether and then acid-catalyzed epoxide ring opening, gives the diol 15 (yields in this sequence are unoptimized). Chromium trioxide promoted oxidative cyclization of this substrate proceeded to give 40% of THF diol 14, along with a 14% isolated yield of the aldehyde 16 resulting from over oxidation of diol 14. This aldehyde, which exists primarily as the expected hemiacetal, affords a 93% yield of THF 14 upon reduction with sodium borohydride. Thus, the total yield of THF 14 from diol 15 by this approach was 53%. While the Cr(VI)-promoted oxidative cyclization process proceeds in higher yield than the permanganate-promoted process in this system, the extra steps involved in proceeding by this pathway makes it a somewhat less attractive option in this application. Of course, demonstration of the efficacy of the Cr(VI)-promoted process in this system is interesting since it suggests a possible approach to preparation of the target molecules in enantiomerically enriched form.

Completion of the synthesis is straightforward from THF diol 14. Thus, treatment of THF 14 with TsCl gives the primary tosylate, which cyclizes to the bicyclic ether 17 upon treatment with NaH in DMF. Debenzylation by catalytic hydrogenation, followed by RuO_4 oxidation,[15] esterification, and then desilylation gives the known hydroxy ester 18.[16] This ester is identical with material prepared at Ortho and converted by the Ortho group to the zoapatanol bicyclic acid 3a by a straightforward route.[16,17]

Studies directed toward accomplishing the conversion of bicyclic ether 17 to zoapatanol itself are under way.

Acknowledgment. Grateful acknowledgment is made for support of this work through NSF Grant No. CHE-8011391 and Public Health Service Grant GM31051 from the National Institute of General Medical Sciences.

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(17) We thank Dr. R. Chen and Dr. S. D. Levine of Ortho Pharmaceutical Corp. for their assistance in this identification.
(18) Alfred P. Sloan Foundation Fellow, 1982-1986; Dreyfus Teacher-Scholar, 1983-1985.

Supplementary Material Available: Spectral and analytical data for all new compounds (10 pages). Ordering information is given on any current masthead page.

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Preparation and Rearrangement of *trans*-3-(Allyloxy)acrylic Acids: A Claisen Sequence That Avoids Mercury Catalysis

Summary: Reaction of sodium or lithium salts of primary and secondary allylic alcohols with (*E*)-(carboxyvinyl)-trimethylammonium betaine affords (*E*)-3-(allyloxy)acrylic acids, which on heating are transformed to γ,δ-unsaturated aldehydes.

Sir: The Claisen rearrangement of allyl vinyl ethers,[1] although a potentially very useful synthetic transformation, has severe limitations due to the lack of efficient general methods for the preparation of allyl vinyl ethers. These intermediates are normally prepared by vinyl ether exchange with simple alkyl vinyl ethers and an allylic alcohol in the presence of a Lewis acid (usually mercuric acetate) or mineral acid.[2] Yields in these reactions are often low, and the use of mercury is becoming unacceptable due to environmental problems.

Modifications of the Claisen rearrangement (e.g., those of Johnson,[3] Ireland,[4] and Eschenmoser[5]) are more widely applicable; however, all of these give products at the carboxylic acid oxidation level, and additional steps are required if an aldehyde is the desired product.

We have developed a modification of the Claisen rearrangement for primary and secondary allylic alcohols that does not require catalysis by mercury salts or mineral acids and gives aldehydes directly. Furthermore, sealed tubes or other high-pressure vessels are not necessary. The betaine 1[6,7] prepared from ethyl propiolate and trimethylamine was shown to combine with alkoxide to give the corresonding *trans*-3-alkoxyacrylic acids (Scheme I).[7]

Heating the sodium alkoxides of allylic alcohols with the betaine 1 affords moderate to good yields of the corresponding *trans*-3-(allyloxy)acrylic acids 2. Aqueous solutions of the adducts 2, as their sodium salts, are first washed with ether and then acidified to give the adducts 2. These crude products are heated with a trace of hydroquinone at temperatures of 150-200 °C to give the

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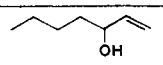
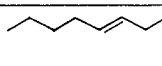
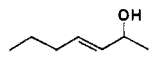
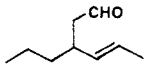
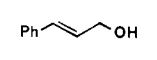
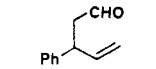
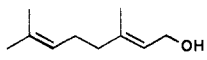
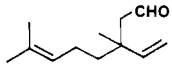
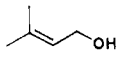
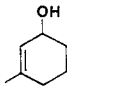
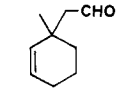
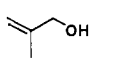
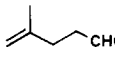
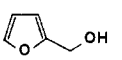
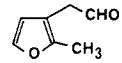
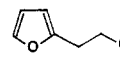
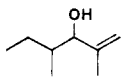
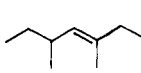
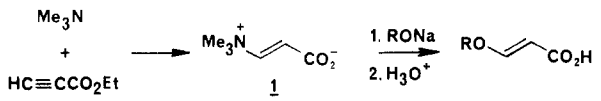
Table I. Formation and Rearrangement of *trans*-3-(Allyloxy)acrylic Acids 2

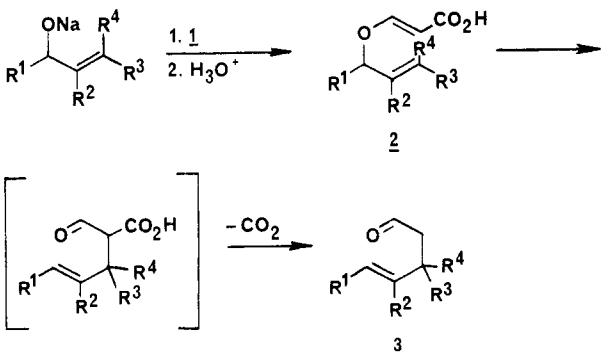
	starting material	yield of 2,[a] %	pyrolysis conditions: temp,[b] °C	pressure, mm	reactn time, h	product 3[c]	yield of 3, %
a		89	160	15	2		68
b		84	150	15	1		78
c		92	200	0.1	1		quant.
d		62	200	15	0.5		quant.
e		96	200	760	0.5		quant.
f		53, 77[d]	165	15	1		quant.
g		73	200	760	1		*e*
h		82	180	15	1		79
							16[f]
i		55[g]	180	15	0.5		82

[a] Conditions for the formation of *trans*-3-(allyloxy)acrylic acids. The sodium alkoxides of the corresponding allylic alcohols were formed with NaH in anhydrous THF, and 1.2 equiv of the betaine **1** was added. The mixture was heated to 65 °C for 14 h. [b] Kugelrohr oven temperature. [c] All compounds were characterized by NMR and IR spectroscopy. All new aldehydes gave satisfactory elemental analyses. Vapor-phase chromatographic analysis of compounds **3a**, **3b**, and **3i** indicated the presence of only one geometrical isomer. [d] THF was replaced by Me_2SO as solvent, otherwise standard conditions were followed. [e] The product was always contaminated with some inseparable impurities. [f] This product was also observed in the pyrolysis (370 °C) of furfuryl vinyl ether: Thomas, A. F. *Helv. Chim. Acta* **1970**, *53*, 605. [g] Reaction conditions: Me_2SO/HMPA, 80 °C, 14 h.

Scheme I



Scheme II



corresponding Claisen rearrangement[8] products with concomitant decarboxylation (Scheme II).

Since the acrylic acids **2** always have a much higher boiling point than the aldehydes **3**, one merely heats the acids under the appropriate reduced pressure such that the product is removed rapidly from the reaction mixture. The aldehydes **3** are isolated in good to excellent yields often in analytically pure form (Table I).

Thus far we have been unsuccessful in the preparation of 3-alkoxyacrylic acids from tertiary alcohols. Replacement of the betaine **1** with propiolic acid led to formation of 3-alkoxyacrylic acids in significantly lower yields. These two and an earlier observation[7] are best accounted for by an addition–elimination process.

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Registry No. **1**, 54299-83-1; **2a**, 88056-80-8; **2b**, 88056-81-9; **2c**, 88083-18-5; **2d**, 88056-82-0; **2e**, 88056-83-1; **25b**, 88056-84-2; **2g**, 88056-85-3; **2h**, 88056-86-4; **2i**, 88056-87-5; **3a**, 2277-16-9; **3b**, 88056-88-6; **3c**, 939-21-9; **3d**, 34687-42-8; **3e**, 919-93-7; **3f**, 60415-75-0; **3g**, 3973-43-1; **3i**, 88056-89-7; 2-methyl-3-furanacetaldehyde, 27394-15-6; 2-furanpropanal, 4543-51-5; 1-hepten-3-ol, 4938-52-7; (*E*)-3-hepten-2-ol, 67077-39-8; (*E*)-3-phenyl-2-propen-1-ol, 4407-36-7; (*E*)-3,7-dimethyl-2,6-octadien-1-ol, 106-24-1; 3-methyl-2-buten-1-ol, 556-82-1; 3-methyl-2-cyclohexen-1-ol,

(8) For substituent effects in the Claisen rearrangement, see: Burrows, C. J.; Carpenter, B. K. *J. Am. Chem. Soc.* **1981**, *103*, 6983 and 6984.

21378-21-2; 2-methyl-2-propen-1-ol, 513-42-8; 2-furanmethanol, 98-00-0; 2,4-dimethyl-1-hexen-3-ol, 88056-79-5.

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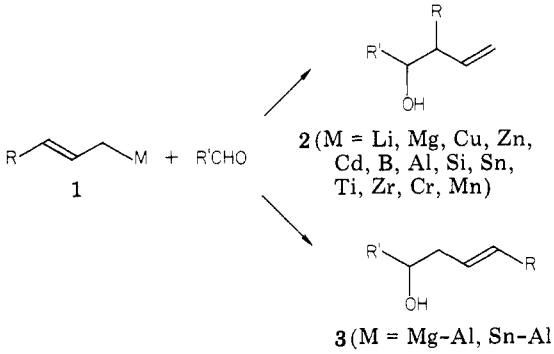
Selective Synthesis of either Branched or Linear Homoallyl Alcohols via the Reaction of Aldehydes with the Allylic Borane–Selenium System

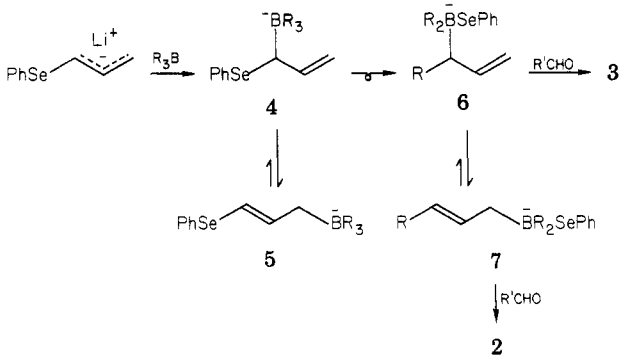
Summary: Either branched (**2**) or linear (**3**) homoallyl alcohols can be prepared independently by choosing the reaction conditions through the reaction of (phenylselenyl)allyl carbanion with trialkylboranes.

Sir: In general, γ-substituted allylic organometallic compounds **1** react with aldehydes to produce branched homoallyl alcohols **2**.[1] Quite recently, we have found that the



linear isomer **3** can be obtained through the combination of the certain allylic organometallics with aluminum derivatives.[2] The selective synthesis of either branched or linear homoallyl alcohols is becoming increasingly important for control of acyclic stereochemistry;[3] the former type of reaction is useful for a 1,2 asymmetric induction in acyclic systems, while the latter alcohols can be converted into the tetrahydrofuran derivatives with alkyl substituents at the 2,5 positions. We now report that either branched or linear alcohols can be prepared at will from the single starting material by merely choosing the reaction conditions.

The key of our procedure is based on the findings that the alkyl group of R_3B in complex **4** undergoes a facile migration from boron to the α carbon[4] and that the allylic rearrangement of the resulting boron–selenium complex **6** to **7** is slow in comparison with the usual allylic boranes.[5]



To a solution of 1.2 mmol of freshly prepared lithium diisopropylamide dissolved in 10 mL of THF was added allyl phenyl selenide (1 mmol, 0.13 mL) at −78 °C under nitrogen atmosphere, and the mixture was stirred for 30 min at this temperature: method A, R_3B (3 mmol) was added at −78 °C and the resulting mixture was kept at 0 °C for 1 h; method B, R_3B (3 mmol) was added at −78 °C and the resulting mixture was kept at room temperature for 12 h; method C, R_3B (1 mmol) was added at −78 °C and the resulting mixture was kept at room temperature for 12 h. After an appropriate operation among these three methods, the mixture was again cooled to −78 °C and an aldehyde (1 mmol) was added. The reaction was quenched at room temperature with H_2O. Excess boranes were oxidized with H_2O_2–NaOH as usual. The ratio of **3** to **2** was investigated at this stage.

The results are summarized in the Table I. Method A provides the linear adduct either predominantly or exclusively. The short rection period at lower temperature must suppress the allylic migration from **6** to **7**.[7] The prolonged reaction period at room temperature completes the migration, giving the branched adduct (method B). Interestingly, use of 2 equiv of R_3B with method B (at room temperature for 12 h) causes a decrease of **2** and an increase of **3**. For example, the ratio of **2**/**3** from benzaldehyde was 91:9 with 3 equiv of Et_3B, while the ratio

Table I. Selective Synthesis of Either Branched or Linear Homoallyl Alcohols[a]

aldehyde	R_3B	method	homoallyl alcohol,[b] % 3 (*E*:*Z*)	homoallyl alcohol,[b] % 2 (erythro:threo)	total yield,[c] %
C_6H_5CHO	Et_3B	A	94 (86:14)	6	88
	Et_3B	B	9	91 (24:76)	89
	n-Bu_3B	B		~100 (12:88)	92
	Et_3B	C	~100 (88:12)		45[d]
p-$CH_3C_6H_4CHO$	Et_3B	A	>99 (~100:0)	trace	90
	Et_3B	B		~100 (36:64)	92
p-$CH_3OC_6H_4CHO$	Et_3B	A	71 (*e*)	29 (*e*)	80
	Et_3B	B	8	92 (14:86)	81
p-$O_2NC_6H_4CHO$	Et_3B	C	77 (*e*)	23 (*e*)	65[d]
	Et_3B	B		~100 (18:82)	93
n-C_3H_7CHO	Et_3B	B		~100 (25:75)	85
n-$C_9H_{19}CHO$	Et_3B	B		~100 (39:61)	83

[a] All reactions were carried out on a 1-mmol scale as described in the text. [b] By ^1H NMR and GLPC analysis (PEG 6000, 5%, 2 m). [c] Isolated (combined) yield through a short column. When a mixture of 3 and 2 was obtained, separation was performed through silica gel chromatography using hexane–ether (20:1) as eluant. In some cases, the reduced product of the starting aldehyde was accompanied, presumably owing to the reduction with the ate complexes (**4**–**7**).[6] [d] The reaction was incomplete and the aldehyde was recovered. [e] Not determined.

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