Reaction of the Cyclic Organoboranes from Dienes with Methyl Vinyl Ketone. A Convenient Synthesis of ω-Hydroxy-ketones from Dienes *via* Hydroboration

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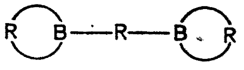
Summary Cyclic organoboranes react with methyl vinyl ketone to provide a new route to ω-hydroxy-ketones.

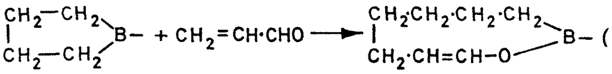
TRIALKYLBORANES, readily available *via* hydroboration,[1] undergo a remarkably ready reaction with many αβ-unsaturated carbonyl compounds, such as methyl vinyl ketone,[2] acraldehyde,[3] methacraldehyde,[4] and α-bromoacraldehyde[4] to form the corresponding ketones or aldehydes in excellent yields (equation 1).

$$\begin{array}{l} R_3B + CH_2{:}CH{\cdot}CHO \xrightarrow{25^\circ} RCH_2{\cdot}CH{:}CHOBR_2 \qquad (1) \\ \qquad\qquad\qquad\qquad\qquad\qquad \downarrow H_2O \\ \qquad\qquad\qquad\qquad\quad RCH_2{\cdot}CH_2{\cdot}CHO + R_2BOH \end{array}$$

It has been reported that the hydroboration of dienes, such as buta-1,3-diene,[5,6] isoprene,[7] penta-1,3-diene,[7,8] and hexa-1,5-diene,[8] produces cyclic organoboranes which are distillable. Although no satisfactory proof of the structure of the products has yet been described,† these authors have indicated that the reaction products possess the following general "dumb-bell" structure where R = C_nH_{2n} (n = 4, 5, or 6) and R may consist of one or more isomeric units.



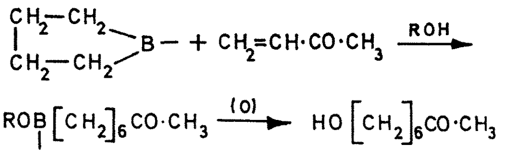
The question was whether cyclic boron compounds of this type could undergo the 1,4-addition, a process which would conceivably require the formation of 9- and 10-membered ring intermediates (equation 2).



(2)

Accordingly, we selected buta-1,3-diene and penta-1,4-diene as representative dienes and methyl vinyl ketone as a representative αβ-unsaturated carbonyl derivative. The reaction proceeds quite readily at 25° or in refluxing tetrahydrofuran (THF). Consequently, it is questionable that the formation of 9- and 10-membered ring intermediates can be involved in the reactions.‡

The organoborane from buta-1,3-diene, treated with methyl vinyl ketone in the presence of propan-2-ol,§ followed by oxidation with alkaline hydrogen peroxide, gave an 85% yield of hydroxy-ketones containing 8-hydroxyoctan-2-one¶ and its isomer** in a ratio of 70 : 30 (equation 3).



(3)

The hydroboration of penta-1,4-diene appears to go preferentially to the formation of a 2-methylboracyclopentane moiety.[9] Consequently, it is not unexpected that

Synthesis of ω-hydroxyalkan-2-ones by reaction of the organoboranes derived from buta-1,3-diene and penta-1,4-diene with methyl vinyl ketone

Diene	Thermal treatment (hr.)	Methyl vinyl ketone[a]	Propan-2-ol[a]	Temp.[b] (°)	Product, % (I)[c]	(II)[d]	Yield %
Buta-1,3-diene	0	2	0	68	78	22	74
	0	2	2·5	68	72	28	85
	0	4	2·5	25	73	27	84
	6	2	0	68	94	6	52
	6	2	2·5	68	95	5	62
	6	4	0	25	94	6	64
	6	4	2·5	25	94	6	74
Penta-1,4-diene	0	2	0	68	39	61	66
	0	2	2·5	68	24	76	73
	0	4	2·5	25	35	65	92
	6	2	0	68	94	6	51
	6	2	2·5	68	88	12	65
	6	4	0	25	89	11	58
	6	4	2·5	25	92	8	66

[a] Moles per atom boron. [b] Refluxing THF solution was approximately 68°. All reactions were run for 24 hr., although many were complete sooner. [c] 8-Hydroxyoctan-2-one from buta-1,3-diene or 9-hydroxynonan-2-one from penta-1,4-diene, [d] 7-Hydroxy-5-methylheptan-2-one (presumably) from buta-1,3-diene or 8-hydroxy-5-methyloctane-2-one from penta-1,4-diene.

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† A detailed study of these materials is under way in our laboratories.

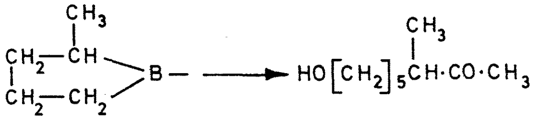
‡ The mechanism of this 1,4-addition reaction is currently under study with George W. Kabalka and will be reported shortly.

§ The hydrolysis of enol borinate intermediates which was achieved with water in the case of simple trialkyboranes, [2-4] resulted in the hydrolysis of the starting organoboranes from buta-1,3-diene which was competitive with the 1,4-addition. Fortunately, the hydrolysis is slower with propan-2-ol, yet this alcohol adequately solvolyses the enol borinate.

¶ The compound gave satisfactory elemental analysis and spectral date in agreement with the assigned structure.

** The isomer is presumably 7-hydroxy-5-methylhepten-2-one arising from 1,3-hydroboration of buta-1,3-diene.[1] It was not fully characterized, since it was always a minor product.

the major product from treatment of the organoborane with methyl vinyl ketone (equation 4) is 8-hydroxy-5-methyloctan-2-one¶ (65%), with the straight-chain isomer, 9-hydroxynonan-3-one¶ being the minor product (35%) (Equation 5). The combined yield was 92%.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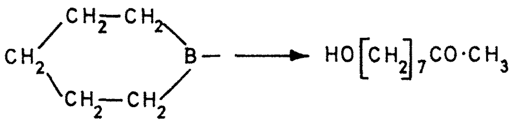
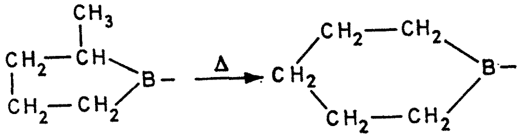

(5)

The isomeric purity of the products was improved greatly by subjecting the organoboranes to thermal treatment at 170° (isomerization conditions for organoboranes[1]), before reaction with methyl vinyl ketone. Thus the isomeric purity of 8-hydroxyoctan-2-one from buta-1,3-diene product was increased from 70 to 95%. In the case of the product from penta-1,4-diene, the major product was altered by this thermal treatment from 8-hydroxy-5-methyloctan-2-one to 9-hydroxynonan-2-one. Evidently, the thermal conditions convert the boracyclopentane moiety into the boracyclohexane structure†† (equation 6).


(6)

The results are summarized in the Table.

The following procedure is representative of the general synthesis. Buta-1,3-diene (650 mmole) in THF (400 ml.) was hydroborated with borane in THF (400 mmole) at 0°. After 24 hr. at 25°, 10 mmole of the organoborane solution was treated with propan-2-ol (50 mmole) and methyl vinyl ketone (40 mmole) under reflux for 24 hr. The alkaline hydrogen peroxide oxidation provided the hydroxy-ketones (17 mmole, 85% based on boron,‡‡ preparative g.l.c. yield). The products are readily isolated by distillation or preparative g.l.c. Before distillation it is advantageous to remove the diol by-products by washing them out from an ether extract with cold water. In experiments in which a large excess of methyl vinyl ketone was used, it simplified the isolation procedure to remove the excess of reactant by distillation before the oxidation.

For experiments in which the organoborane was subjected to isomerizing conditions, the THF was distilled from the organoborane and the latter heated at 170° for 6 hr. The product was cooled, THF added, and the reaction with methyl vinyl ketone and propan-2-ol carried on as previously described. All operations were carred out under nitrogen with exclusion of air.

It is becoming evident that cyclic, bicyclic, and polycyclic organoboranes with a wide variety of structures are readily synthesized.[10] The present results are highly promising for extension of the reaction of $\alpha\beta$-unsaturated carbonyl compounds to these interesting intermediates.

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†† A detailed study of such isomerizations is underway.

‡‡ In the reaction of trialkylboranes with $\alpha\beta$-unsaturated carbonyl derivatives, only one alkyl group is reactive per boron atom.[2–4] Consequently, the yield is based on a theoretical production of one mole of product per mole of boron used.

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[10] For a brief review, with pertinent literature references, see H. C. Brown, *Accounts Chem. Res.*, 1969, **2**, 65.