We feel that we have established beyond question that monocarboxylic acids are the major component of synthetic vitamin B'_{12}. These could also arise quite naturally on storage of solid B_{12} compounds, which usually contain large numbers of H_2O molecules. The dicarboxylic acids from acid hydrolysis cannot be excluded as the additional species in noncrystalline vitamin B'_{12} observed by HPLC. The ^1H NMR spectrum of the dicarboxylic acid fraction contains signals that are obscured by the larger monocarboxylic acid signals. The B'_{12} spectrum contains several additional signals (e.g. at 6.15 and 6.45 ppm)—and thus, all the impurities in the noncrystalline B'_{12} sample cannot be the components in the dicarboxylic acid fractions.[6] Since "natural" vitamin B'_{12} itself is a trace impurity (0.08%),[2] the other components in "B'_{12}" are insignificant indeed. In any case, the physical and chemical measurements reported thus far on vitamin B'_{12} (e.g. the reported 360-MHz ^1H NMR spectrum[2]) must represent primarily the properties of the monocarboxylic acid mixture.

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Supplementary Material Available: Comparison of the visible spectra of the mixture of monocarboxylic acids and B'_{12} and tables of positional parameters and structure factors (30 pages). Ordering information is given on any current masthead page.

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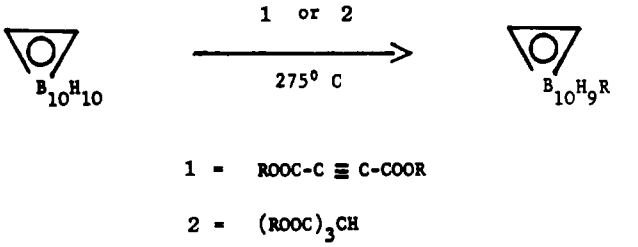
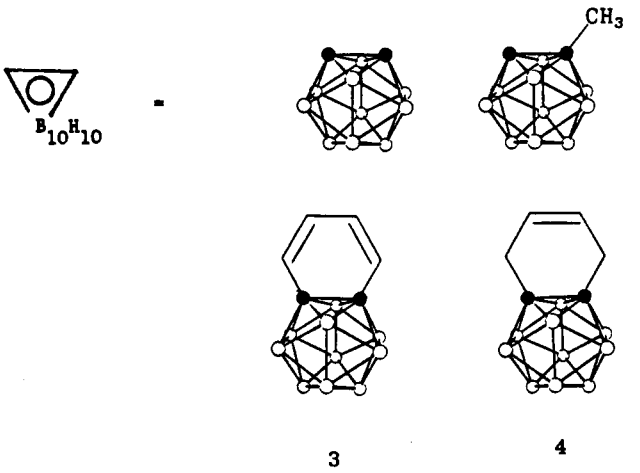
Alkylation of *o*-Carborane by Ester Pyrolysis[1]

Sir:

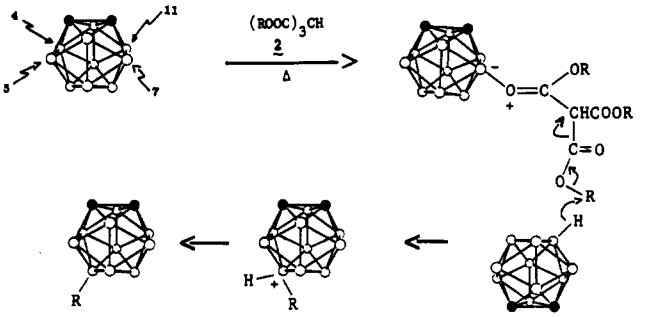
Efficient substitution of the (9,12)-position in *o*-carborane cannot be achieved through simple Friedel–Crafts alkylation. Books on boron hydride chemistry give this reaction short shrift,[2] and for good reason. The reports of such alkylation reactions are sparse and contradictory,[3,4] as remarked by Zakharkin and his co-workers[4] in the most detailed description of the reaction. They found that introduction of a single ethyl group on boron accelerated further substitution until four groups had added. As a result mixtures were obtained and the utility of simple alkylation is clearly limited. Nor are alternate procedures without difficulty. Although the reported replacement of a 9-iodo group by the alkyl group of a Grignard reagent works well,[5] at least in our hands the required synthesis of 9-iodo-*o*-carborane[6] does not.[7]

Scheme I

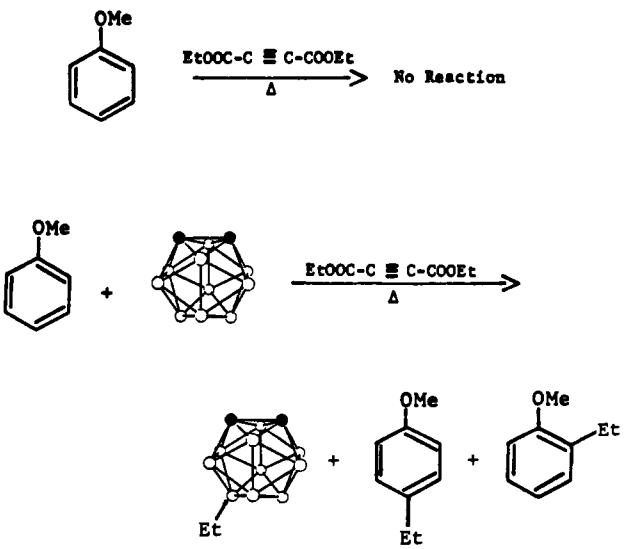




Scheme II



Scheme III



(1) We thank the National Science Foundation for support of this work through Grant CHE-8318345. We also express our appreciation for support from the donors of the Petroleum Research Fund, administered by the American Chemical Society. Dr. José Zayas kindly synthesized authentic samples of 9-*n*-propyl- and 9-isopropyl-*o*-carborane.

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(3) Fielding, T. E. Ph.D. Thesis, University of Pittsburgh, 1971; *Diss. Abstr. Int., B* **1972**, *32*, 6891.

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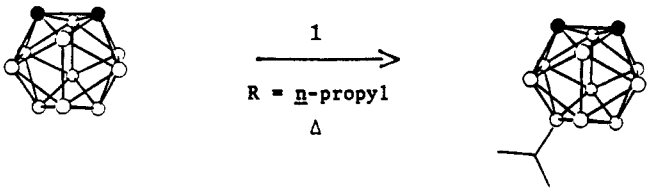
Scheme IV



We have discovered that simple pyrolysis of *o*-carboranes in the presence of certain esters in sealed tubes at 200–275 °C produces 9-alkyl-*o*-carboranes in reasonable yield (Scheme I). Although some polyalkylation does occur with small "R" groups, for "R" larger than methyl it is not a serious impediment to synthesis of the monoalkyl compounds. For instance, after 48 h at 250 °C, *o*-carborane and **2** yield a product mixture containing 75% unreacted *o*-carborane, 22% 9-ethyl-*o*-carborane, and 3% 9,12-diethyl-*o*-carborane. Products were isolated by preparative gas chromatography and identified by precise mass spectrometry and ^{1}H, ^{13}C, and ^{11}B NMR spectroscopy.

The esters of choice are dialkyl acetylenedicarboxylates (**1**) and trialkyl methanetricarboxylates (**2**). Other esters also work but are substantially less efficient. We have successfully applied this alkylation procedure to *o*-carborane, 1-methyl-*o*-carborane, and the two 1,2-bridged carboranes **3** and **4**. Substitution at carbon seems to be unimportant to the success of this reaction. The difficulty of alkyl transfer increases with the size of the alkyl group. Thus in a series of dialkyl acetylenedicarboxylates the ease of alkyl transfer was methyl > ethyl > propyl > *sec*-butyl. We have been unable to transfer a *tert*-butyl group.

We suggest that *o*-carborane is acting as a mild catalyst in this Friedel–Crafts-like alkylation reaction. Esters are known to alkylate aryl compounds in the presence of catalysts.[8] For the carboranes there is an added requirement for elevated temperature as the borons lack the empty p orbital of catalysts such as boron trifluoride. However, the role of acceptor could be played by the LUMO of *o*-carborane located roughly in the band of four equivalent borons (4, 5, 7, 11) in the center of the icosahedron[9] (Scheme II).

That *o*-carborane is not merely a passive recipient of the alkyl group is shown by the following experiment: anisole, though an activated aromatic compound toward electrophilic substitution, is unaffected by heating in **2** for 46 h at 275 °C, above which temperature **2** is destroyed (Scheme III). Addition of *o*-carborane to a mixture of anisole and triethyl methanetricarboxylate resulted not only in specific alkylation of the carborane at the 9(12)-position, but formation of ethylanisoles as well. Support for the notion that this is a polar reaction comes from the observations that substitution occurs at the most nucleophilic B–H bond and that di-*n*-propyl acetylenedicarboxylate gives 9-isopropyl-*o*-carborane when heated to 275 °C with *o*-carborane (Scheme IV). We were careful to show that isomerization of 9-*n*-propyl-*o*-carborane does not take place under the reaction conditions. Were the reaction to involve radicals, one would not expect the *n*-propyl to isopropyl rearrangement so common in cation chemistry.[10] The failure of monoesters such as phenyl propiolate to undergo the reaction well indicates that the alkyl group transferred is that of the uncomplexed ester.

Why are **1** and **2** so much more successful than other esters? It appears that the ester groups remaining after transfer and loss of CO_2 serve to stabilize the residual fragment of the starting ester. Thus **2** leaves behind two ester groups to stabilize the intermediate, but dimethyl malonate, which just barely undergoes the reaction, contributes but one. As required by this mechanism, CO_2 is a product of the reaction and dialkyl malonate can be detected from the reaction of *o*-carborane and **2**. Similarly, tetraethyl ethenetetracarboxylate is far more successful as a transfer agent than either dialkyl maleates or fumarates.

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