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Hindered Organoboron Groups in Organic Chemistry. 20. Alkylations and Acylations of Dimesitylboron Stabilised Carbanions

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Abstract. The alkylation of carbanions derived from alkyldimesitylboranes is an efficient process leading to *prim*-$RBMes_2$, *sec*-$RBMes_2$ and *tert*-$RBMes_2$, all of which can be derived from $MeBMes_2$. Subsequent oxidation gives a general synthesis for *prim*-ROH. Secondary alkanols are also produced on oxidation, but the release of *t*-alkanols has not been accomplished in an efficient fashion. Studies are given of the acylation of dimesitylboron stabilised carbanions.

We have previously published reports on the generation of carbanions α to a dimesitylboron group and their methylation as part proof of carbanion production.[1,2] We have also examined the methylation of dimesitylmethylborane and benzyldimesitylborane[3] and disclosed our preliminary findings on alkylations of alkyldimesitylboranes.[4] We now give details of our alkylation and acylation studies on anions derived from alkyldimesitylboranes.[5]

1. ALKYLATIONS

A priori it appeared that dimesitylmethylborane (1) could be a general precursor of *prim*-alkanols (4), *sec*-alkanols (7), and *tert*-alkanols (10) by reactions outlined in Scheme 1. In this Scheme, the primary aim is to produce the boranes (3), (6) and (9) for which are available all the very many reactions of organoboranes.[6] We chose oxidation as a facile process generally involving a small anion, HO_2^-, to illustrate the synthetic potentialities of the alkylations. From Scheme 1, it can be seen that $Mes_2B\bar{C}R^1R^2$ is the synthetic equivalent of the hypothetical $HO\bar{C}R^1R^2$.

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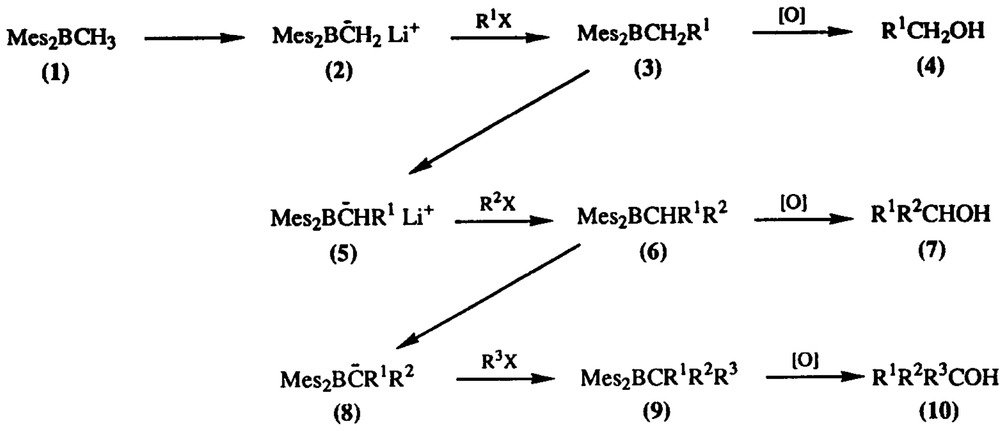


Scheme 1

Such a general Scheme raises various questions that must be addressed. These include: (a) what is the most efficient base to produce the carbanions; (b) what is the influence, if any, of the conjugate acid of the base on subsequent reactions; (c) what alkyl halides can be utilised for alkylation; (d) under what conditions in boranes (6) and (9) does boron migrate along the chain to less hindered positions (e) what oxidation conditions are required to produce the alkanols from the borane precursors ?

1.1 *Influence of the base used for carbanion preparation.*

We previously showed[1] that lithium dicyclohexylamide ($LiNChx_2$) and mesityllithium (MesLi) were each capable of quantitatively generating carbanion (2) from (1). We examined the rates of carbanion production from (1) and from dimesitylethylborane, $Mes_2BCH_2CH_3$ (11), using methylation as a probe (eq. 1). Initial studies showed that methylation was almost instantaneous, and that (1), (11) and dimesitylisopropylborane, $Mes_2BCH(CH_3)_2$ (12) could each be isolated in >95% from reaction mixtures as air-stable, crystalline solids. Analyses are then rather simple using ^1H nmr spectra. Compound (1) has a methyl peak showing as a singlet at δ1.50, compound (11) has a methyl peak showing as a triplet at δ1.03 and (12) has two methyl peaks showing as a doublet at δ1.08.

$$\underset{(1)}{Mes_2BCH_3} \xrightarrow[2.MeI]{1.\ Base} \underset{(11)}{Mes_2BCH_2CH_3} \xrightarrow[2.MeI]{1.\ Base} \underset{(12)}{Mes_2BCH(CH_3)_2} \qquad (1)$$

For the process (1) goes to (11) *via* (2), it was found by rapid sampling and quenching that, regardless of the order of addition of base and (1), carbanion production was complete in 15min using $LiNChx_2$ and in 60min using MesLi. From the somewhat more hindered borane (11), carbanion production using $LiNChx_2$ now took 30min but was still complete in 60min using MesLi, indicating that the latter base was less influenced by steric hindrance.

For other boranes, ^1H nmr analysis is not so straightforward and therefore the alkylation products were oxidised to the corresponding alkanols, which were analysed by g.c. The absolute yields of the alkanols was partly a function of the oxidation, but for the immediate purpose of this study we were interested in the minimum time for the disappearance of the starting material (as well as yields). The results are given in Table 1.

Table 1

Minimum reaction times for the generation of carbanions from Mes_2BPr^n (13), Mes_2BHept^n (14), and Mes_2BOct^n (15)

Experiment	$Mes_2BCH_2R^1$	Base	R^2I	Time (h)[a]	% Yield R^1R^2CHOH[b]
1	(13)	MesLi[c]	Pr^nI	1.0	80
2	(13)	MesLi[c]	Pr^nI	2.0	82(75)
3	(14)	MesLi[c]	MeI	1.0	62
4	(14)	MesLi[c]	MeI	2.0	81
5	(14)	MesLi[d]	MeI	2.0	83(75)
6	(15)	MesLi[c]	MeI	1.0	58
7	(15)	MesLi[c]	MeI	2.0	76
8	(15)	MesLi[c]	MeI	12.0	77
9	(15)	$LiNChx_2$[c]	MeI	24.0	50

a) Time for carbanion generation. b) G.c. yields (isolated yields) from borane.
c) Haloalkane added to carbanion. d) Carbanion added to haloalkane.

The first noteworthy observation was that *the carbanions derived from (13),(14) and (15) were stable for 24h at 25°C*, regardless of the base used for their generation. Secondly, comparison of experiments 7 and 9 show that, with boranes of greater steric hindrance than (1) and (11), $LiNChx_2$ requires far longer times for carbanion generation than MesLi, as suspected from our previous experiments. *In all cases tried in Table 1, mesityllithium gives the required carbanions in 2h or less at room temperature.* Moreover, yields of alkanols are synthetically useful.

1.2 *Types of halides that can be utilised*

For this study we used Mes$_2$BCH$_2$Li (2) and varied the alkyl halide. Alkylation with iodomethane was complete in 2 min at 25°C in 96-98% isolated yield regardless of which base had been used to generate (2). We then turned to less active halides, of which we used one equivalent in each case. The results are given in Table 2.

Table 2

Alkylation/Oxidation of Mes$_2$BCH$_2$Li (2) using 1 equivalent of haloalkenes

Experiment	Base	Alkylating agent	Temp (°C)	Time (h)	%Yield of RCH$_2$OH[a]
10	LiNChx$_2$[d]	Oct^{n}I[b]	25	0.25	94(80)
11	LiNChx$_2$	Oct^{n}I[c]	25	0.25	92(83)
12	LiNChx$_2$	Oct^{n}I[b]	0	0.25	94
13	LiNChx$_2$	Oct^{n}Br[b]	25	0.25	96
14	LiNChx$_2$	Hept^{n}I[b]	25	0.25	94(80)
15	LiNChx$_2$	Hex^{n}Br[b]	25	0.25	96(83)
16	MesLi	Hept^{n}I[b]	25	0.25	95(87)
17	MesLi	Hex^{n}Br[b]	25	0.25	67
18	MesLi	Hex^{n}Br[b]	25	15	91
19	MesLi	PentCHBrMe[b]	25	0.25	26
20	MesLi	PentCHBrMe[b]	25	15	26
21	MesLi	PentCHBrMe[b]	-25	0.25	26
22	MesLi	EtCH(OTs)CH$_3$[b]	25	0.25	0
23	MesLi	CH$_3$CH(OMes)CH$_3$[b]	25	0.25	0
24	MesLi	ChxBr[b]	25	0.25	0

[a] G.C. yield (isolated yield) from borane. [b] Haloalkane added to carbanion.
[c] Carbanion added to haloalkane. [d] Chx = cyclohexyl.

In all cases, regardless of base used, carbanion (2) is readily alkylated with primary alkyl iodides in 15min at 25°C. Dropping the temperature to 0°C (exp. 12) did not affect the reaction. It seems that the presence of dicyclohexylamine facilitates alkylation (compare exp. 13, 15, 17, 18), and the addition of amine bases to alkylation reactions, regardless of whether or not the amines are used in carbanion generation, may well be generally useful. *sec*-Alkyl bromides give low yields of alkylated product, (exp. 10, 20, 21) the halide being quantitatively accounted for as alkene. A *sec*-tosylate (exp. 22) and *a sec*-alkyl mesylate (exp. 23) as well as a cycloalkyl bromide (exp. 24) failed to give any alkylation product at all. Clearly the alkylations are confined to *prim*-alkyl halides, the iodides being most effective, but the bromides also giving excellent yields.

Table 3

Alkylation of (2) with $PhCH_2X$

Experiment	Base	$PhCH_2X$ (equiv)	Temp(°C)	Time(h)	%Yield of $PhCH_2CH_2OH^a$
25	$LiNChx_2$	$PhCH_2Br(1)^b$	25	0.25	62(56)
26	$LiNChx_2$	$PhCH_2Br(1)^b$	25	15	61
27	$LiNChx_2$	$PhCH_2Br(1)^b$	-78	0.25	61
28	$LiNChx_2$	$PhCH_2Br(1)^b$	60	0.25	45
29	$LiNChx_2$	$PhCH_2Br(1)^c$	25	0.25	60
30	$LiNChx_2$	$PhCH_2Br(0.5)^b$	25	0.25	32^d
31	$LiNChx_2$	$PhCH_2Br(2)^b$	25	0.25	40
32	MesLi	$PhCH_2Br(1)^b$	25	0.25	62
33	$LiNChx_2$	$PhCH_2Cl(1)^b$	25	0.25	45
34	$LiNChx_2$	$PhCH_2I(1)^b$	25	0.25	85(74)

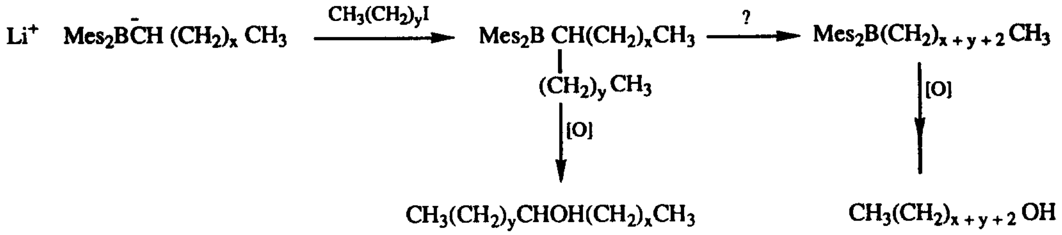
a) G.C. yield (isolated yield) from borane. b) Haloalkane added to carbanion.
c) Carbanion added to haloalkane. d) Based on benzyl bromide.

To our surprise, benzyl bromide was a less efficient alkylating agent than octyl bromide under the same conditions (compare exp. 13 and 25). This is presumably a steric effect. Increasing the time of reaction (exp. 26) or using a lower temperature (exp. 27) or inverse addition (exp. 29) or an alternative base (exp. 32), did not improve the situation, and raising the temperature lowered the yield (exp. 28), as did use of excess borane. Benzyl chloride (exp. 23) was less effective than the bromide, but benzyl iodide gave a satisfactory result (exp. 34).

In conclusion, it has been shown that use of carbanion (2) resulted in a rapid, general and efficient homologation from R^PI to R^PCH_2OH

1.3 *Synthesis of* sec-*alkanols.*

We now examined the conversion of (5) to (7) in Scheme 1. In this case, it was of primary importance to establish whether or not boron was able to migrate along the alkyl chain to a less hindered position,[7] as in some cases this isomerisation is surprisingly easy. Thus it occurs at room temperature in the hydroboration of 1-methylcyclooctene and in refluxing THF for 1h for the products of hydroboration of cyclooctadiene. In an investigation of the migration of boron in dialkyl-3-hexylboranes, Brown showed that the bulkier the alkyl groups, the easier were the migrations.[8,9] Our fear therefore was that, using our very bulky alkyldimesitylboranes, the migrations shown in Scheme 2 would occur and that this would stop the possibility of preparing *sec-* or *tert*-alkanols by the projected reactions shown in Scheme 1.



Scheme 2

In the event, we were pleased to find that dimesityl-B-2-octylborane (16) was completely stable in THF at 0°C, in refluxing THF and refluxing glyme (90°C) for 6h. After refluxing in diglyme at 160°C for 2h, the ratio of (16) to the *n*-octyl derivative (15) was 94:6, as shown by oxidation and quantitative g.c. We have reported,[10] in preliminary form on the thermal stability of alkyldiarylboranes and details will be given in a further, full paper in this series.

Being assured of the configurational stability of the possible alkylation products (6), we looked for optimum alkylation conditions for the anion $Mes_2BCHLiCH_3$ (17) derived from $Mes_2BCH_2CH_3$ (11), the parent, least hindered, representative of boranes (3). Some results, using iodohexane as alkylating agent, are given in Table 4.

Table 4

Reactions of $Mes_2BCHLiCH_3$ (17) with Hex^nI

Experiment	Equiv. of Hex^nI	Base	Temp (0°C)	Time (h)	%Yield of $HexCHOHCH_3$[a]
35	1.1	$LiNChx_2$	25	5.0	35
36	1.1	MesLi	25	5.0	49
37	1.1	MesLi	25	0.25	42
38	1.1	MesLi	0	0.25	68
39	1.1	MesLi	0	0.5	76
40	1.1	MesLi	0	2.0	78
41	1.1	MesLi	0/65	0.5/3.0	84(70)
42	1.1	Mesli	-78	12.0	70
43	1.1	MesLi	-78/25	12/1.0	80
44	0.5	MesLi	0	0.5	82(74)[b]

a) G.C. yield (isolated yield). b) Based on Hex^nI.

Experiments 35 and 36 showed that for iodohexane (and presumably other long chain iodoalkanes) it was advantageous to use MesLi as base for anion formation, and therefore MesLi was used subsequently. Addition of hexyl iodide at 25°C led to violently exothermic reactions that were difficult to control and this probably accounts for the low yields in experiments 35, 36, 37. Dropping the temperature to 0°C and leaving for 30 min (exp. 39) gave a reasonable yield of the alkanol, and leaving for longer (exp. 40) or warming after the addition (exp. 41) only slightly enhanced that yield. Reactions could be successfully carried out at -78°C (exp. 42, 43), and use of excess borane gave a good yield of product, the yield in that case being based on iodohexane (exp. 44).

We therefore decided to standardise further alkylations using the rapid, convenient procedure of experiment 39, realising that this might not be optimal in any specific case. The results are given in Table 5.

Table 5

Alkylations of $Mes_2BCHLiR^1$ with R^2I

Experiment	R^1	R^2 (equiv.)	% Yield of R^1CHOHR^2 [a]
45	Me	Bu^n(1.1)	76
46	Me	Bu^n(0.5)	96[b]
47	Me	$Hept^n$(1.1)	85(70)
48	Me	Oct^n(1.1)	82
49	Me	$PhCH_2$(1.1)	78(60)
50	Et	Pr^n(1.1)	82(75)
51	Et	$Pent^n$(1.1)	66
52	Hex^n	Me(1.0)	92
53	Hex^n	Me(1.0)	91

[a] G.c. (isolated yields). [b] Yield based on Bu^nI.

In all cases in which the product is represented by $Mes_2BCH(R)Me$ yields of alkanol are >75%, this therefore being a synthetically useful general method for the production of RCHOHMe.

In one case, $Mes_2BCH(Et)Pent^n$, the yield dropped to 66%. We believe that our standard conditions did not give efficient oxidation of this, the most hindered borane. In one case (exp. 50) the intermediate borane m.p. 54-56°C was isolated in 86% yield.

An *in situ* process shown in Scheme (3), was tried with success. The yield of nonan-2-ol based on (15) was 77% overall. *Hence it is feasible not only to proceed from* $Mes_2BCH_2R^1 \longrightarrow R^1R^2CHOH$*, but to use* Mes_2BCH_3 *(1) as a general precursor, as shown in Scheme 1.*

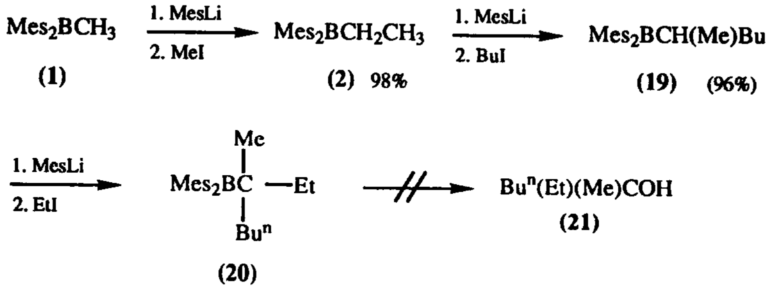
$$\begin{tikzcd} \mathrm{Mes_2BCH_3} \arrow[r, "\text{1. MesLi}", "\text{2. Hept}^{n}\text{I}"'] & \mathrm{Mes_2BCH_2Hept} \arrow[r, "\text{1. MesLi}", "\text{2. MeI}"'] & {[\mathrm{Mes_2BCH(Me)Hept}]} \arrow[d, "{[O]}"] \\ \text{(1)} & \text{(15) (94\%)} & \mathrm{HeptCH(OH)Me} \\ & & \text{(77\%)} \end{tikzcd}$$

Scheme 3

1.4 *Synthesis of R_3CBMes_2 (9) and attempted preparation of R_3COH (10)*

We have already reported[3] the conversion of (1) to Mes$_2$BBu^t (18) and of Mes$_2$BCH$_2$Ph to Mes$_2$BCMe$_2$Ph by successive methylation steps. We had not, however, converted such compounds to the corresponding alkanols.

Compound (18) was oxidised to Bu^{t}OH with 50% H_2O_2/5MNaOH in propanol/THF in a yield of 95% in 3h at 25°C. This seemed to indicate that oxidation of compounds (9) (Scheme 1) should not present too great difficulties. In order to generalise the process we carried out the syntheses outlined in Scheme 4.



Scheme 4

As already shown, the yield of (2) from (1) and (19) from (2) are >95% yield for each step. The isolated yield of (20) was 70% overall, showing that this is an effective synthesis. We did not attempt to vary the order of introduction of the groups in order to maximise the yields and it may be that the final alkylation would be more efficiently performed with iodomethane rather than iodoethane. *Clearly the triple alkylation sequence in Scheme 1 can be performed successfully and generally.* It seemed that (20) represented only a minor variation of *t*-butyldimesitylborane (18) and we were therefore surprised that application of our standard conditions of oxidation to (20) gave no 3-methylheptan-3-ol at all. Therefore in this oxidation we are reaching the predicted limit[1] of our steric approach to boron stabilised carbanions, in that the boron atom of (20) is so encumbered that even the small hydroperoxide anion is unable to coordinate to it. Our solution to the problem by substituting the mesityl groups by 2,6-dimethyl-4-methoxyphenyl (DMP) groups and switching attack to the activated aromatic groups has already been outlined[11] and will be given in full later in this series. However, the lack of oxidation of (20) under standard conditions forced us to look carefully at the oxidation of alkyldimesitylboranes.

1.5 *The oxidation of alkyldimesitylboranes.*

We first examined the oxidation of Mes$_2$BCH$_2$R (R = Me, Et, Pr^n, Bu^n, Hex^n, Hept^n, Oct^n, benzyl) and found that the corresponding alcohols were readily and almost quantitatively produced using a five-fold excess of each of 50%H_2O_2 and 3M or 5M NaOH at 25°C/15h or at 68°C/1h.

Examination of Mes$_2$BCH(Me)R(R=Bu^n, Hex^n, Hept^n, Oct^n) showed that the same conditions gave >90% of the derived alkanols regardless of the length of the alkyl chain.

However, oxidation of $Mes_2BCH(R)Et$ (21) proved rather more difficult, as did the oxidation of $Mes_2BCR^1R^2R^3$. Table 6 gives the results of oxidations of (22) (R = Pr^n, Pent^n).

Table 6

Oxidation of $Mes_2BCH(R)Et$ (22) by 50% alkaline hydrogen peroxide

Experiment	R	T(°C)	Time(h)	%Yield of RCHOHEt^a
54	Pr^n	25	12	55
55	Pr^n	68	12	82(75)
56	Pent^n	25	12	36
57	Pent^n	68	12	58
58	Pent^n	68	72	66^{b,c}

$^{a)}$ G.C. yields (isolated yield). $^{b)}$ H_2O_2 replenished every 12h. $^{c)}$ Borane still present after 72h.

Satisfactory yields of hexan-3-ol were obtained from (22) (R = Pr^n) by heating under reflux for 12h. However (22) (R = Pent^n), with a slightly longer alkyl chain proved more recalcitrant, and even after 72h reflux gave only 66% of octan-3-ol.

The *t*-alkylborane (20) gave 36% yield of 3-methylheptan-3-ol (21) after heating as a 1M solution in THF at 65°C for 24h with five-fold excess of 50% H_2O_2/5M NaOH. The use of 70% H_2O_2 on neat (20) at 25°C/24h gave only 16% of (21), enhanced only to 20% when a solution of the borane in THF was oxidised in the presence of a phase transfer catalyst.

Alternative procedures for oxidations of alkyldimesitylboranes were examined. One representative oxidant is *m*-chloroperbenzoic acid (MCPBA)[6,7,12] and another is trimethylamine-N-oxide-dihydrate (TMNO).[6,7,13] The results using these two oxidising agents are shown in Table 7.

Table 7

Oxidations of $Mes_2BCR^1R^2R^3$ by MCPBA and TMNO

Experiment	R^1	R^2	R^3	Oxidant	T (°C)	Time (h)	%Yield of $R^1R^2R^3COH^a$
59	Hept^n	H	H	TMNO	25	24	0
60	Hept^n	H	H	TMNO	160	24	70
61	Hept^n	H	H	MCPBA	25	15	100
62	Hept^n	H	H	MCPBA	60	15	68
63	Hex^n	Me	H	MCPBA	25	15	5
64	Prop^n	Et	H	MCPBA	25	15	0
65	Bu^n	Et	Me	MCPBA	25	15	0
66	Bu^n	Et	Me	TMNO	160	15	0

$^{a)}$ G.C. yields.

The reactions with MCPBA were executed by adding twice the stoichimetric amount (6 equiv.) of MCPBA to a 0.25M chloroform solution of the borane. Reactions with TMNO used three times the stoichimetric amount of oxidant, which was added to a 0.8M solution of the borane in diglyme. Experiment 61 shows that MCPBA is an efficient oxidant of R^PBMes_2 and that it offers an alternative, non-basic anhydrous oxidation procedure. However, MCPBA cannot be used for R^sBMes_2 or R^tBMes_2. Trimethylamine-N-oxide is a poor oxidant for all alkyldimesitylboranes.

Certain aryldimesitylboranes have been degraded by a sequential mercuration/bromination process[14] as in equation 2.

$$\text{1-NaphthylBMes}_2 \xrightarrow[\text{2. 3Br}_2]{\text{1. 3Hg(OAc)}_2\text{/HOAc}} \text{1-Br-naphthalene} + \text{2MesBr} \qquad (2)$$

In accordance with this procedure, tertiary-alkylborane (20) was treated with three equivalents of 0.15M mercuric acetate in anhydrous acetic acid and, after 20 min reflux, with three equivalents of bromine. The bromine colour disappeared at once, but alkaline work-up gave a complex mixture of unidentified products.

The sensitivity of organoboranes to oxygen is well known,[6,7,15] and the process constitutes a quantitative conversion of trialkylboranes to alcohols (eq. 3).[15]

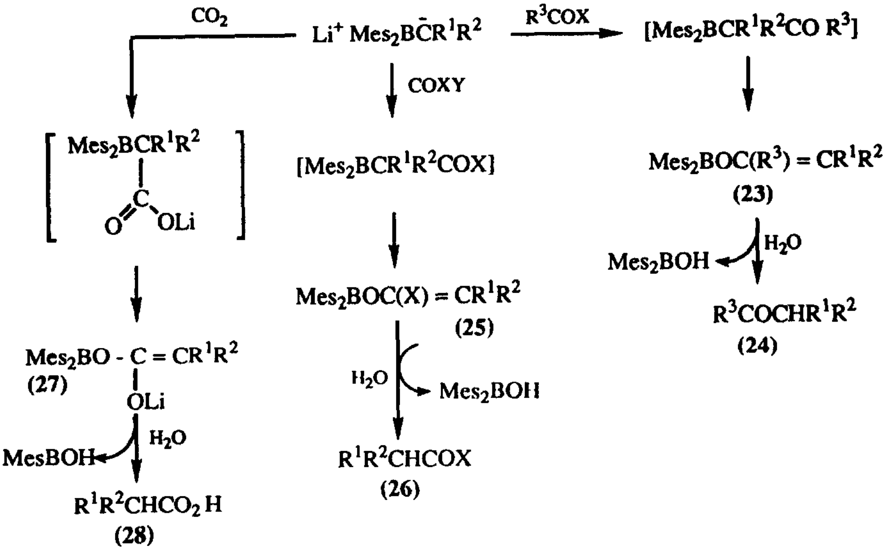
$$R_3B \xrightarrow{1.5O_2} R_{1.5}B(OOR)_{1.5} \xrightarrow{\text{NaOH}} (RO)_3B \xrightarrow{H_2O} 3ROH \qquad (3)$$

It was therefore all the more striking that the *tert*-alkylborane (20) was recovered unchanged when oxygen was bubbled through a 1M solution in refluxing THF for 15h, followed by treatment with 3M NaOH.

Hydrolysis of (20) with isobutyric acid in diglyme under reflux for 15h was also attempted but analysis of the mixture showed no reaction and therefore no further oxidation was tried.

2. ACYLATIONS.

The acylation of boron stabilised carbanions might have potential as a route to dimesitylboryl enolates (23), ketones (24), dimesitylboryloxyketene ethers (25), esters (26) ($X=OR^4$) and acids (28), according to Scheme 5. This Scheme is of interest because of the great attention focussed on (23) and (25) for selective aldol condensations.[16,17]



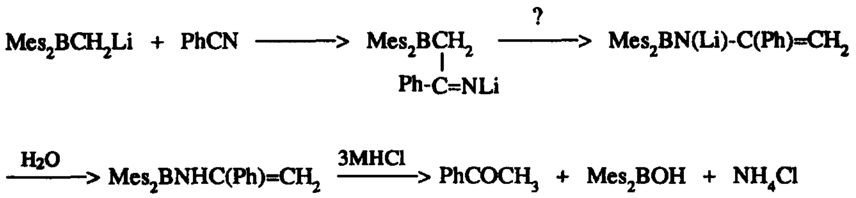
Scheme 5

2.1 *Approaches to ketone syntheses.*

The introduction of a benzoyl group, which lacks any protons α- to the carbonyl group, on to anion (2) was chosen as a model system to investigate the acylations of Scheme 5 (eq. 4).

$$\underset{(2)}{\mathrm{Mes_2BCH_2Li}} + \mathrm{PhCOX} \xrightarrow{\quad ? \quad} \mathrm{PhCOCH_3} + \mathrm{Mes_2BOH} + \mathrm{LiX} \qquad (4)$$

We first found that generation of (2) using LiNChx$_2$ was disadvantageous due to competing amide formation giving low yields [36% (PhCOCl) and 43% (PhCO)$_2$O)] of acetophenone. Subsequently, all experiments used MesLi for anion generation. Addition of benzoyl chloride (1 equiv.) to (2) at 25°C for 30 min, followed by addition of water gave acetophenone in 55% yield, which did not increase after 12h. Recovered borane (1) accounted for the rest of the material, the yield on the borane converted being 100%. Use of two equivalents of PhCOCl only raised the yield to 63%. Methyl benzoate reacted with (2) to give a 72% yield of acetophenone after 2 min at 25°C. The reaction was time sensitive and the yield dropped to 56% after 30 min and 21% after 12h. Benzoic anhydride gave a 32% yield in 2 min, benzoyl imidazole gave 23%, and no acetophenone could be obtained by use of N,N-dimethylbenzamide. Benzonitrile reacted with anion (2) in 2h at 25°C but gave no acetophenone on addition of water. However, addition of 3M HCl gave acetophenone in 52% yield (Scheme 6).



$$\mathrm{Mes_2BCH_2Li} + \mathrm{PhCN} \longrightarrow \underset{\mathrm{Ph\text{-}C{=}NLi}}{\mathrm{Mes_2BCH_2}} \xrightarrow{?} \mathrm{Mes_2BN(Li)\text{-}C(Ph){=}CH_2}$$

$$\xrightarrow{\mathrm{H_2O}} \mathrm{Mes_2BNHC(Ph){=}CH_2} \xrightarrow{\mathrm{3MHCl}} \mathrm{PhCOCH_3} + \mathrm{Mes_2BOH} + \mathrm{NH_4Cl}$$

Scheme 6

Further work on this acylation was discouraged when it was found that benzoylation of the slightly more hindered carbanion, $\mathrm{Mes_2BCHLiCH_3}$ (17) by a variety of reagents gave propiophenone in low yields only. The best yield was 35% using either PhCOCl or $\mathrm{PhCO_2Me}$ in either ether or THF.

Acylation of (2) with methyl octanoate was totally unsuccessful in a variety of conditions (*e.g.* -78°C to 25°C) though the ester was consumed. In each case (1) was recovered in >90% yield. With octanoyl chloride the best yield of methyl octyl ketone obtained was 10%, using a wide variety of conditions and, once again, (1) was present in >90% yield. Clearly the boron stabilised carbanion had abstracted an α-proton from the acylating agent in both cases, as its sole or major reaction pathway.

2.2 *Attempts to produce esters.*

Acylation of $\mathrm{Mes_2BCHLiHex^n}$ (29) with ethyl chloroformate (eq. 5) proved to be a difficult reaction. The best yield (55%) of ethyl octanoate was obtained by dropping the carbanion into a 100-fold excess of neat ethyl chloroformate at -25°C for 15 min.

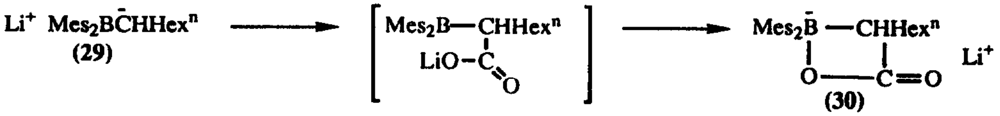
$$\underset{(29)}{\mathrm{Mes_2BCHLiHex^n}} \xrightarrow[\text{2. } \mathrm{H_2O}]{\text{1. } \mathrm{ClCO_2Et}} \mathrm{HexCH_2CO_2Et} + \mathrm{Mes_2BOH} \tag{5}$$

Use of dimethyl carbonate at 50°C gave no methyl octanoate but instead oxidation of the reaction mixture gave octan-2-ol (49%) and *n*-heptanol (42%). Thus dimethyl carbonate reacted as a methylating agent, a reaction with literature precedent,[18] rather than as an acylating agent.

2.3 *Attempts to produce carboxylic acids.*

The reaction of organolithium compounds with carbon dioxide to give carboxylate salts is generally an efficient reaction, and has been used for the analysis of organolithium compounds.[19]

We therefore attempted the carboxylation of (29) by passing dried carbon dioxide into a 0.5M solution of (29) in THF. Whether at 0° or at 25°C the carbanion colour was instantly discharged and the i.r. of the product, after removal of solvents and mesitylene in high vacuum, had a strong absorbance at 1800 cm^{-1}. From this we surmise that the carbon dioxide reaction did not proceed so as to give the ketene acetal derivative (27) (Scheme 5) but instead gave a borato-β-lactone (30) (eq. 6)



(6)

The intermediate, presumably (30) was thermally stable for 24h at 25°C and showed remarkable hydrolytic stability. Almost no reaction could be detected after 15h at 25°C in the presence of a large excess of water. Quenching with 3M HCl however, led to extensive decarboxylation (evolution of CO_2) and only 20% yield of octanoic acid was obtained, along with 20% of Mes_2BOH. Dimesityl-B-*n*-heptylborane was recovered in 80% yield. This is not unreasonable, as the intermediate (30) on acid hydrolysis would give $Mes_2BCH(Hept)CO_2H$, which is isoelectronic with a β-keto acid. Attempts to methylate (30) with methyl iodide were unsuccessful even under forcing conditions.

Conclusions.

Alkylations of anions derived from B-alkyldimesitylboranes are efficient reactions which offer general syntheses of *prim-* and *sec*-alcohols. Although the *tert*-alkylboranes are efficiently made, they cannot be readily oxidised to the corresponding *tert*-alcohols. Acylations of boron stabilised carbanions show, as yet, little synthetic promise.

Experimental

Technical Information

Infra-red spectra were recorded on a Pye Unicam SP1050 infra-red spectrometer using NaCl cells with neat liquids or solutions and KBr disks with solids. The polystyrene absorbances at 1603 cm^{-1} and 1494 cm^{-1} were used as references. Proton nmr were recorded on a Hitachi Perkin-Elmer R-24B spectrometer at 60 MHz, a Varian HA-100 spectrometer at 100 MHz and a Bruker WM-250 spectrometer at 250 MHz using $CDCl_3$ as solvent and Me_4Si as reference except where stated. Boron (^{11}B) nmr were recorded on a Varian XL--100 Fourier transform nmr spectrometer, using boron trifluoride etherate in a co-axial cell as external standard and quartz nmr tubes. Signals downfield from the BF_3 (*i.e.*, deshielded) were recorded as positive and the chemical shifts are in ppm. Carbon (^{13}C) nmr were recorded on a Varian XL100 or a Bruker WM-250 Fourier transform nmr spectrometer, using $CDCl_3$ as a solvent and Me_4Si as an internal standard except where stated. Low resolution c.i. and e.i. mass spectra were recorded on an AEI MS9 mass spectrometer, a GC12-253 mass spectrometer, or a VG ZAB-E mass spectrometer.

Melting points were recorded on a Gallenkamp Hot Stage apparatus and were uncorrected. Boiling points were determined by Kugelrohr distillation and the temperature given is that of the Kugelrohr oven. Thin layer chromatography was performed on silica gel (Merck) mounted on aluminium cards with fluorescent indicator (254 nm). Preparative chromatographic separations were achieved using silica (Merck) as an absorbent in a glass column, using U.V. detection.

Gas liquid chromatograms were run on a Pye Series 104 programmed chromatograph (Model 64) fitted with a Servoscribe 1s potentiometric recorder and LDC Model 308 computing integrator. Mixtures containing volatile low molecular weight alcohols were analysed on a 6' x ¼" glass column packed with 12% Carbowax 20M on Chrom W AW/DMCS 100-120 mesh (70-190°C, 10°C/min). Mixtures containing volatile ketones, esters and haloalkanes were analysed on a 6' x ¼" glass column packed with 5% SE30 on Chrom W AW/DMCS 100-120 mesh (70 - 300°C, 12°C/min). G.c. estimations of reaction yields were made by adding a known weight of a standard to the reaction mixture and determining the detector response factor for each component to be examined. Typical internal standards were straight chain hydrocarbons like tridecane or hexadecane. Identification of components was made by co-injection of authentic samples with the mixture under examination.

All reactions involving organoboranes were carried out using purified anhydrous reagents unless otherwise stated. Reactions involving the use and production of air and water sensitive compounds were carried out under a static pressure of argon or nitrogen used directly from the cylinder through a glass line directly connected *via* a three-way tap to a vacuum pump. The preparation and purification of reagents for use in reactions of organoboron compounds have been recently reviewed.[20] Solvents were treated as follows.[21] THF was purified first by passing through dry, neutral alumina under nitrogen or argon. Sodium (2g per litre) and benzophenone (8g per litre) were then added to the THF in a still and the mix stirred under argon to give a purple solution of the sodium benzophenone ketyl. The THF was then distilled from the ketyl, under argon, as required. Glyme, diethyl ether, petroleum ether and cyclohexane were passed through an alumina column, stirred for 16 hours with calcium hydride and distilled from calcium hydride under nitrogen or argon. Carbon tetrachloride and ethyl acetate were purified by distillation from phorphorus pentoxide. Methanol was dried and purified by distillation from magnesium methoxide.

Mesityl bromide was distilled under nitrogen, at reduced pressure prior to use. All other reagents were distilled under nitrogen prior to use. Solutions of *n*- and *t*-butyllithium in hexanes and methyllithium in ether were obtained from Aldrich and standardised every three to four weeks by direct titration of the carbon-lithium bond with butan-2-ol using 1,10-phenanthroline as indicator.[22] Iodoalkanes were prepared[5] in excellent yields from the corresponding bromides by the Finkelstein exchange reaction[24] and distilled or recrystallised immediately prior to use.[25]

Experimental Procedures

The equipment and techniques involved in laboratory operations with air sensitive substances have been surveyed.[20] All glassware was oven dried (typically >24 hours at 120°C) assembled hot, and allowed to cool under a stream of nitrogen or argon introduced *via* needles inserted through serum capped inlets with outlets protected by inert oil bubble. Manipulation of liquids was carried out under an inert atmosphere, using syringes and double-ended needle techniques. Syringes and double-ended needles were flushed with nitrogen as they cooled. Solids were transferred, either in air without delay and flushed with nitrogen prior to reaction, or by using a dry box.

Unless otherwise stated, the apparatus for reactions consisted of a septum capped flask equipped with a spiral inlet arm which is wholly immersed in the cooling bath.[23] The flask contains a coated magnetic follower to enable stirring of the reaction mixture *via* an external magnetic stirrer. A bleed needle to the argon line was inserted through the cap to allow for any changes in the pressure within the vessel during reaction. The apparatus for reactions at elevated temperatures consisted of a two-necked round-bottomed flask; one neck equipped with a septum capped tap adaptor, the other with a septum capped reflux condenser carrying a nitrogen bleed. Again, a magnetic stirrer provided a method for agitation of the reaction mixture.

Procedures for the preparation of anions derived from Mes_2BR^p=Me, Et, Pr^n, $Hept^n$, Oct^n.

(i) A 50ml round-bottomed flask was charged with THF (25ml) and dicyclohexylamine (1g, 5.5mmol) and cooled to 0^0C. The solution was stirred whilst Bu^nLi (5.5mmol of a freshly standardised solution, *ca.* 1.5M in hexane) was added dropwise. Stirring was continued for 15 min and then the solution was transferred to the neat borane, weighed into a similar flask and held at 25°C. Reaction was exothermic to give orange or red solutions, which were stirred for 15 min (R=Me) or 30 min (R=Et).

(ii) Bromomesitylene (1.1g, 5.5mmol) was made up to a 0.5M solution in a round-bottomed flask by addition of THF (11ml). The flask was cooled to -78°C and Bu^tLi (2 equiv. of a freshly standardised solution, normally about 1.8-2.0M in hexane, was added. The solution became pale yellow and a white solid precipitated. The mixture was stirred for 15 min at -78°C, then placed in a bath at 25°C for 15 min during which the precipitate dissolved. The reaction mixture containing MesLi (5.5mmol) was transferred *via* a double-ended needle to the previously weighed out B-alkyldimesitylborane (5mmol) at 25°C and the mixture stirred for 1h (R=Me, Et) or 2h (all other R^pBMes_2).

General procedure for one carbon homologation reactions

The haloalkane (5mmol) was added dropwise to a well stirred solution of Mes_2BCH_2Li (2) prepared according to procedure (i). The pink reaction mixture was stirred for 15 min, then methanol (10ml) and dodecane (0.5g) were added. The flask was cooled to 0°C and then 5M NaOH (5ml) was added, followed by a slow, careful addition of 50% H_2O_2 (2.5ml) with vigorous stirring. The mixture was stirred at 25°C for 15h (or at 68°C/1h) to complete the oxidation, extracted with pentane (3 x 50ml) and the combined extracts dried ($MgSO_4$) and filtered. Estimations by g.c. were carried out at this stage, the solvent being made up to a known volume in a volumetric flask. The results are given in Tables 2 and 3.

The solvent was removed by distillation to give a pale oil which was transferred with a little pentane to the top of a silica column (150g). Elution with pentane (100ml) removed the dodecane and dichloromethane (100ml) and dichloromethane/ether (75ml, 40:1, v/v) removed the 2,4,6-trimethylphenol (MesOH). Elution with ether/chloroform (100ml, 1:1, v/v) gave the homologated, primary alcohols, which were then distilled.[25] (Table 2, exp. 10, 11, 14, 15) or crystallised (Table 3)[25]. Each alcohol was compared with an authentic sample by g.c., i.r., and ^{1}H n.m.r.

A variant of this procedure (exp. 16) used procedure (ii) to make anion (2) and gave the homologated alcohol in 87% yield. A check on the efficiency of the oxidations was made using R^pBMes_2 produced from Mes_2BF by the Grignard method.[1,3,4] In general this gave between 92-95% of alcohol.

Alkylation of anions from Mes_2BR^p (R=Et, Pr^n, Hep^n, Oct^n) to give secondary alcohols.

The anions (5mmol) were produced using MesLi by procedure (ii). The anion solution was cooled to 0°C and the iodoalkane (5mmol) was added by syringe to the well stirred reaction mixture. Stirring was continued for 30 min and then the reaction was treated with 5M NaOH/50% H_2O_2 as in the one-carbon homologation procedure. Isolation of the product secondary alcohols was also carried out by the preceding procedure, the results being given in Tables 4 and 5.

*Preparation of dimesityl-B-3-hexylborane.**

The anion from dimesityl-B-*n*-propylborane (4.4g, 15mmol) was made by procedure (ii). To the stirred solution of the anion at 25°C was added iodopropane (2.55g, 1.46ml, 15mmol) dropwise by syringe, and the reaction mixture was stirred for a further 1h. It was then added to water (20ml), extracted with ether (3 x 20ml) and the combined ether extracts washed with 0.2M sodium thiosulphate (20ml) and water (20ml), dried ($MgSO_4$) and filtered. Concentration of the filtrate followed by pumping for 12h at 50°C/2mm Hg removed the solvent and mesitylene. The yellow oil remaining (one clear peak by h.p.l.c.) crystallised slowly on standing under nitrogen to give *product* (4.3g, 86%), m.p. 54-56°C. δ_H 1.5(13H, m, alkyl C-*H*), 2.2(18H, s, ArCH_3), 6.7 (4H, s, H-3').✱ δ_B 81.3.

Preparation of 3-dimesitylboryl-3-methylheptane (20).

Dimesitylborane (11) was prepared quantitatively by methylation of Mes_2BCH_3 (1) as previously described.[1,3] Its anion (17) (5mmol) was prepared using procedure (ii) and reacted for 30 min at 0°C with iodobutane (0.94g, 5mmol). Solvent was removed at 0.5mm Hg at 35°C for 1h, after which the residue was washed twice with pentane (10ml). In each case the supernatent layer, containing (20) (^{1}H nmr) was transferred to a 10ml round-bottom flask fitted with a magnetic follower and tap adaptor. The residue left in the reaction flask consisted of inorganic salts and some (*ca.* 10%) unreacted (17), as shown by addition of water and isolation of (11). The combined pentane extracts were evaporated and mesityllithium (5mmol, procedure (ii)) was added with stirring at 25°C. A mildly exothermic reaction resulted and a deep red colour developed immediately. The reaction mixture was stirred at 25°C for 15h then cooled to 0°C and iodoethane (0.80g, 5mmol) was added. After 30 min stirring the pink solution was poured into water (20ml) and extracted with ether (2 x 20ml). The combined ether extracts were washed with 0.1M sodium thiosulphate (10ml), water (10ml), the organic layer dried ($MgSO_4$), filtered and concentrated to give a pale yellow oil from which mesitylene was removed at 40°C/0.2mm Hg for 1h. Column chromatography (light petroleum) gave (20) (1.27g, 70%) as a single compound by h.p.l.c. using a variety of systems. Attempted distillation at 10^{-3}mm Hg led to decomposition and

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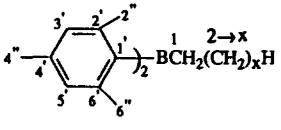
*We thank Dr. A. Keating for the details of this procedure.

✱ For this and all subsequent compounds the numbering used is as follows.



attempts at crystallisation were unsuccessful. δ_H 0.68(6H, t, $CH_3(CH_2)_3C_q{}^*$ and CH_3CH_2), 0.9-1.7(br. m., 4 x CH_2), 1.13(s, CH_3-C_q), 2.17(6H, s, H-4"), 2.30(12H, s, H-2"), 6.72(4H, s, C-3'). δ_C 9.0($CH_2CH_2CH_3$), 13.9(CH_2CH_3), 21.0(C-4"), 23.7(B-C_q-CH_3), 25.7(C-2"), 40.9(B-C_q), 23.0, 27.1, 28.7, 35.4 (4 x CH_2), 129.1(C-3'), 136.9(C-4'), 138.6(C-2'), 143.5(C-1'). δ_B 87.8 (see references 3, 5 for comparison with Mes_2BBu^t).

*Oxidation of dimesityl-B-*n*-hexylborane with* m*-chloroperbenzoic acid.*

A 25ml round-bottomed flask was charged with dimesityl-B-*n*-heptylborane (0.27g, 0.78mmol), chloroform (2ml) and tridecane (0.18g). The flask was cooled to 0°C and MCPBA (1.21g, 7.02mmol) slowly added, after which the reaction mixture was stirred for 24h at room temperature, during which a white precipitate formed. 1M Sodium carbonate (10ml) was added, on which the precipitate dissolved, and the mixture was extracted with ether (2 x 10ml). The combined extracts were washed with 0.1M sodium thiosulphate (10ml), 1M Na_2CO_3 (10ml), dried ($MgSO_4$), filtered and evaporated to give a yellow oil (0.36g) with a negative boron flame test. The g.c. yield of heptan-1-ol in the oil was determined to be 100%, the only other compound present by g.c., h.p.l.c. and t.l.c., was MesOH.

*Oxidation of dimesityl-B-*n*-heptylborane with trimethylamine-N-oxide.*

A 25ml round-bottomed flask was charged with dimethyl-B-*n*-heptylborane (0.27g, 0,78mmol), TMNO dihydrate (0.78g, 7.03mmol) and diglyme (2ml) and the mixture heated under reflux for 24h. Tridecane (0.16g) was added to the cooled mixture which was then poured into water (20ml) and extracted into ether (20ml). The ether layer was washed with brine (10ml), dried ($MgSO_4$), filtered and the ether removed to give a pale yellow oil. Assay by g.c. showed that it contained heptan-1-ol (70%) and also unreacted starting material.

General procedure for optimisation of acylation reactions.

A solution of the desired anion (5mmol, procedure (ii)) containing an internal standard, frequently tridecane (*ca.* 0.5g), was brought to the desired temperature and the appropriate acylating agent (RCOX, RCN) was added with stirring. Aliquots (1ml) at 2, 10, 30, 60, 120 min and 15h were removed and added to water (1ml) at 25°C. After 2 min, ether (2ml) was added and then ammonium chloride (1g). The organic layer was then analysed by g.c. and t.l.c., following which it was removed and concentrated for ^1H nmr analysis.

Benzoylation of Mes_2BCH_2Li (2) with methyl benzoate.

Anion (2) (1.37mmol) was prepared according to procedure (ii), in the presence of dry tridecane (0.2g). Methyl benzoate (0.19g, 1.37mmol) was added to the stirred solution at 25°C, on which an exothermic reaction occurred. After 2 min water (2ml) was added, followed by ether (10ml) and ammonium chloride (2g). The g.c. yield of acetotophenone in the ether was 72%. Water (20ml) was added, and the mixture extracted with ether (2 x 10ml) and the combined organic extracts dried ($MgSO_4$) and concentrated to give a yellow oil (0.93g). Addition of pentane (1.5ml) gave dimesitylborinic acid (0.35g, 1.32mmol, 96%) as white needles m.p. 139-140°C (lit.[26] 140-141°C). The pentane soluble fraction was evaporated and subjected to column chromatography on silica (30g). Elution with pentane (100ml) and dichloromethane (100ml) removed the internal standard and mesitylene. Elution with $CHCl_3/Et_2O$ mixtures (99:1, 20ml; 49:1, 20ml; 19:1, 20ml) removed residual methyl benzoate and elution with ether gave benzophenone (0.11g, 67%), pure by g.c. and identical in every way with an authentic sample.

$^*C_q$ = quaternary C-1

Benzoylation of (2) with benzoyl chloride.

Anion (2) (1.91mmol) was prepared according to procedure (ii) in the presence of tridecane (0.22g). Benzoyl chloride (0.13g, 0.96mmol) was added, with stirring at 25°C, on which the red colour first faded and then the solution became a deep red. The exothermic reaction was cooled and the reaction continued for 12h at 25°C, after which water (5ml) was added and the mixture was extracted with ether (2 x 10ml). At this stage the g.c. yield of acetophenone was 63%. The work up was then continued as before to give acetophenone (70mg, 0.57mmol, 59%) and dimesitylborinic acid (0.14g, 0.5mmol, 54%). Acidification of the aqueous layer gave benzoic acid (0.05g, 0.38mmol, 39%).

Reaction of $Mes_2BCHLiHex^n$ *with dimethyl carbonate.*

Dimesityl-B-*n*-heptylborane (0.793g, 2.28mmol) was converted to its anion by procedure (ii) in a two-necked flask fitted with a reflux condenser and containing tridecane (0.19g). Dimethyl carbonate (0.2g, 2.28mmol) was added at 25°C to the stirred solution which was then heated to 50°C for 1h. The mixture was cooled to 0°C and oxidised in the standard fashion (see the one carbon homologation procedure) by 5M NaOH/50% H_2O_2. The mixture was added to saturated NH_4Cl solution and ether (5ml) added. Quantitative analysis by g.c. of the ether layer showed the presence of starting material (52%) and dimesityl-B-2-octylborane (48%).

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