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A Mechanistic Study of Hydroboration of 1-Octene with 1,3,2-Dithiaborolane and 1,3,2-Dithiaborinane. Part 1. Synthesis and Kinetic Studies

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ABSTRACT

Alkylthioboranes 1,3,2-dithiaborolane and 1,3,2-dithiaborinane have been synthesized from the reaction of BH_3·SMe_2 with 1,2-ethanedithiol and 1,3-propanedithiol, respectively. These heterocyclic boranes disproportionated significantly during their synthesis. The rate constants, and the enthalpies and entropies of the hydroboration reaction of 1-octene with 1,3,2-dithiaborolane and 1,3,2-dithiaborinane have been investigated, and we have shown that hydroboration with these boranes is slow and proceeds *via* an associative mechanism.

KEY WORDS

Hydroboration, disproportionation, boranes, transition states.

1. Introduction

For several years there has been intense research into the role of hydroborating species and several references by Brown *et al.*[1] testify to the usefulness of these reagents and their versatile application in organic synthesis.[1] Since the discovery of hydroboration by Brown *et al.,* an enormous volume of literature has been accumulated involving the use of this methodology.[2] Over the last three decades a range of different hydroborating agents has been developed, to furnish specific transformations desirable to organic chemists.[2]

However, in recent years, a class of sulphur-based borane compounds, also known as alkylthioboranes, has not received much scrutiny. In the early 1960s Mikhailov and co-workers showed that the reaction of mercaptans with diborane led to a mixture of mono- and bisalkylthioboranes in proportions that depended on the nature of the thiol.[3] The reaction of 1-propanethiol with diborane afforded a mixture containing 73 % of mono(propylthio)borane and 27 % of bispropylthioborane and for 1-butanethiol, the product contained 60 % of the monosubstituted borane and 40 % of the bisalkylthioborane.[3] During their studies, trimers of monosubstituted boranes were observed.[4] In the mid 1960s Pasto *et al.* then demonstrated that reaction of mercaptans with diborane gave rise to a number of different products, depending on the experimental conditions under which the reactions were carried out.[5] Subsequent work by Egan *et al.* showed that heterocyclic derivatives of alkylthioboranes can be synthesized from diborane and 1,2-ethanedithiol, and that the reaction is dependent upon the stoichiometric ratios of the reactants (Scheme 1).[6]

Much attention on alkylthioborane chemistry has been based on hydrolysis, and complex formation with phosphines,[6] amines[7]and sulphides,[8] and only very little on hydroboration.[9,10] Thaisrivongs *et al.*[8] reported hydroboration of a range of alkenes with 1,3,2-dithiaborolane-triethyl amine complex, with the aid of BF_3·OEt_2. However, not much work has been done to date in terms of kinetics and thermodynamics using ^{11}B NMR spectroscopy on alkylthioboranes with a single site available for hydroboration. Our interest in the role of sulphur-containing boranes has stemmed from attempts to moderate the rate at which the hydroboration reaction takes place.

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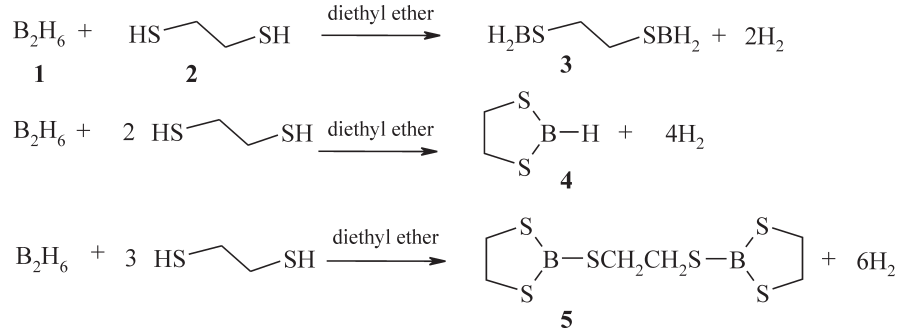
2. Results and Discussion

2.1. Synthesis of 1,3,2-Dithiaborolane

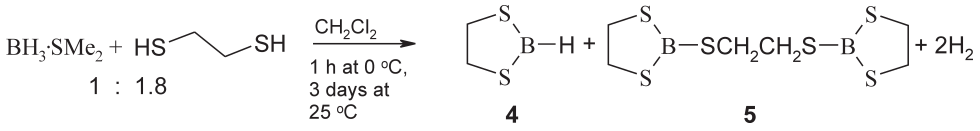
During studies in our laboratory on the synthesis and characterization of heterocyclic derivatives of alkylthioboranes, it was found, based on ^{11}B NMR spectroscopy, that 1,3,2-dithiaborolane (**4**) and the disproportionation product 2,2′-(ethylenedithio)bis-(1,3,2-dithiaborolane) (**5**) were produced from the reaction of BH_3·SMe_2 and 1,2-ethanedithiol (Scheme 2), as was proposed by Egan *et al.*[6] However, the yields of the target molecule (**4**) were significantly hampered by the formation of large amounts of the disproportionation product (**5**). Consequently, different approaches were attempted in the synthesis of this compound in order to optimize the yield of 1,3,2-dithiaborolane (**4**). These approaches included varying the stoichiometric ratio of BH_3·SMe_2 to 1,2-ethanediol, and varying the reaction time and temperature.

Firstly, BH_3·SMe_2 was allowed to react with 1.8 molar equivalents of 1,2-ethanedithiol at 0 °C. ^{11}B NMR analysis showed a small amount of unreacted BH_3·SMe_2 and a doublet at δ 61 ppm (Fig. 1), corresponding to 1,3,2-dithiaborolane (**4**) (Scheme 2). A low yield of *ca.* 48 % was obtained. A singlet at δ 64 ppm was attributed to 2,2′-(ethylenedithio)bis-(1,3,2-dithiaborolane) (**5**) (Scheme 2) with a 50 % yield (Table 1, Entry 1).

The same reaction was conducted at –80 °C and allowed to warm up to room temperature for 15 to 30 min, when it was found that the percentage yield of 1,3,2-dithiaborolane had increased to approximately 50 % of the total mixture (Table 1, Entry 2). Interestingly, an appreciable 71 % yield was achieved upon the use of excess BH_3·SMe_2 at low reaction temperature. The disproportionation product yield was also lower (Entry 3). However, the amount of unreacted BH_3·SMe_2 was slightly



Scheme 1



Scheme 2

higher. It was noteworthy that when equimolar amounts of reactants were used in conjunction with longer reaction times at low temperature, a good 65 % yield was obtained (Entry 7). Maintaining the reaction at low temperature for 14 days did not enhance the yield of 1,3,2-dithiaborolane (**4**) (entry 8), yielding results comparable with entry 1.

Conditions used for entries 1 and 8 were chosen to be the most suitable for the synthesis of 1,3,2-dithiaborolane, to be used in the hydroboration kinetics study, due to the low percentage of $BH_3{\cdot}SMe_2$ obtained. This reduces the possible competition between BH_3 and 1,3,2-dithiaborolane towards the alkene on subsequent hydroboration.

2.2. Synthesis of 1,3,2-Dithiaborinane

A synthetic procedure proposed by Kim *et al.*[11] was used. In this method, borane-dimethyl sulphide complex reacted with an equimolar amount of 1,3-propanedithiol in CH_2Cl_2 at 0 °C and was allowed to stir for a week at 25 °C. Careful ^{11}B NMR spectroscopic analysis of the product mixture showed a doublet at δ 55.7 ppm (Fig. 2), attributed to the desired product, 1,3,2-dithiaborinane (**6**) (*ca.* 35 % yield). A singlet was also observed in the same mixture at δ 57.5 ppm. This was the major product of the reaction (*ca.* 55 % yield) and it was attributed to the disproportionation product 2,2′-(propylenedithio)-(1,3,2-dithiaborinane) (**7**) (Scheme 3). A triplet at δ 16 ppm may be attributed to a mono-substituted borane fragment or the intermediate species in the disproportionation reaction (7 % yield). Some unreacted $BH_3{\cdot}SMe_2$ (3 % yield) was also observed as a quartet. Alternative approaches were employed, as indicated in Table 1. Despite many attempts we were unable to obtain higher yields.

It was found that the alkylthioboranes (compounds **4** and **6**) are highly air- and moisture-sensitive and thermally unstable. Upon exposure to moisture these compounds are rapidly oxidized. This means that the B-H bond breaks and the B-OH bond forms. After oxidation, these reagents are not useful in subsequent hydroboration reactions. At elevated temperatures, these reagents were also shown to disproportionate to (**5**) and (**7**), respectively. Therefore it was of prime importance that these reagents be kept under inert atmosphere and low temperatures (*ca.* 5 °C).

2.3. Hydroboration of 1-Octene with 1,3,2-Dithiaborolane and 1,3,2-Dithiaborinane

During the hydroboration reaction conducted in our study, it was found that the olefin did not react at all with the disproportionation product. It was also interesting to note that no further disproportionation occurred during hydroboration. For both boranes, the desired octyl-boronate esters were characterized by a singlet resonating at δ 70.2 ppm (Fig. 3). No other

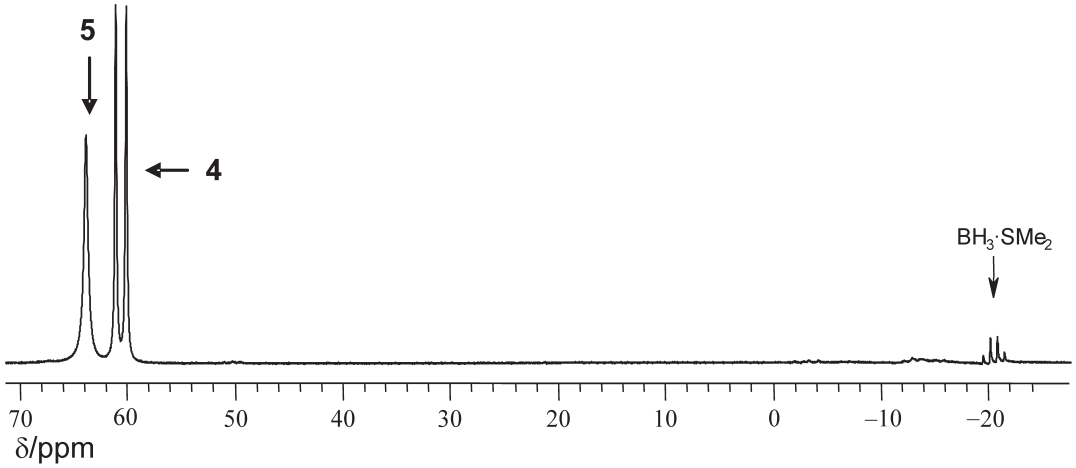


Figure 1 The 160 MHz ^{11}B NMR spectrum, showing a mixture of products obtained in the reaction of 1,2–ethanedithiol with borane-dimethyl sulphide complex.

Table 1 Survey of optimum conditions for the synthesis of 1,3,2 dithiaborolane.

No.	Time	Temperature/°C	Stoichiometric molar ratio		Product yield/%		
			BH_3	1,2-ethanedithiol	**4**	**5**	BH_3
1	1 h	0	1	1.8	48	50	2
2	0.5 h	–80 to 25	1	1.8	50	46	4
3	1 h	–84	1.5	1	71	18	11
4	1 h	–84	1.25	1	64	29	16
5	1 h	–84	1.04	1	45	52	3
6	1.5 h	–84	1	1	55	41	4
2	0.5 h	–80 to 25	1	1.8	50	46	4
3	1 h	–84	1.5	1	71	18	11
4	1 h	–84	1.25	1	64	29	16
5	1 h	–84	1.04	1	45	52	3
6	1.5 h	–84	1	1	55	41	4
7	2 days	–84 to –55	1	1	65	17	18
8	14 days	–84 to –55	1	1	58	40	2

products were formed in this reaction, and no intermediates were observed, based on spectroscopic evidence.

2.3.1. *Concentration Dependence Study*

For both 1,3,2-dithiaborolane (**4**) and 1,3,2-dithiaborinane (**6**), a concentration dependence study was conducted in order to determine the second order rate constant (k_2) for hydroboration of 1-octene. These reactions were conducted under pseudo-first order conditions. In this study, the concentration of the hydroborating agent was kept constant while that of 1-octene was varied from 10× to 25× (the actual concentrations and the methods used are discussed in the experimental section). It was not possible to monitor beyond 25× because the reactions were too fast and went to completion within a few hundred seconds after mixing the reagents.

^{11}B NMR spectroscopy was used to monitor the progress of the hydroboration reaction (Fig. 3). During the course of the reaction, the concentration of the reactant (1,3,2-dithiaborolane) could be seen decreasing with simultaneous formation of the desired alkylborolane. This was more evident when viewed as arrayed spectra, as shown in Fig. 4.

Using the Microcal™ Origin™ 5.0[12] software and fitting the exponential decay for the first order, the plots shown in Fig. 5 were observed, where the experimental data are shown as squares and the smooth curve is the first order exponential decay. Taking the inverse of the first order exponential decay time (t_1) obtained from the software's exponential decay curve fitted in these plots gives the observed rate constant (k_{obs}) at each concentration.

For each concentration, the observed rate constant was obtained. The results obtained from the concentration dependence studies for both (**4**) and (**6**) are summarized in Table 2. Upon comparison of the observed rate constants for both reagents at each concentration and fixed temperature (Table 2), it was shown that both reagents reacted with 1-octene at almost the same rate, as would be expected. Calculation of the second order rate constants for both reactions, from the plots of observed rate constants against concentration, produced linear plots (Fig. 6) with slopes corresponding to the second order rate constants (k_2). For 1,3,2-dithiaborolane this constant was found to be $1.548 \pm 0.009 \times 10^{-4}$ L mol^{-1} s^{-1} and for 1,3,2-dithiaborinane it was found to be $1.652 \pm 0.013 \times 10^{-4}$ L mol^{-1} s^{-1}.

2.3.2. *Temperature Dependence Study*

It was of great importance to conduct a temperature dependence study in order to obtain the activation parameters for

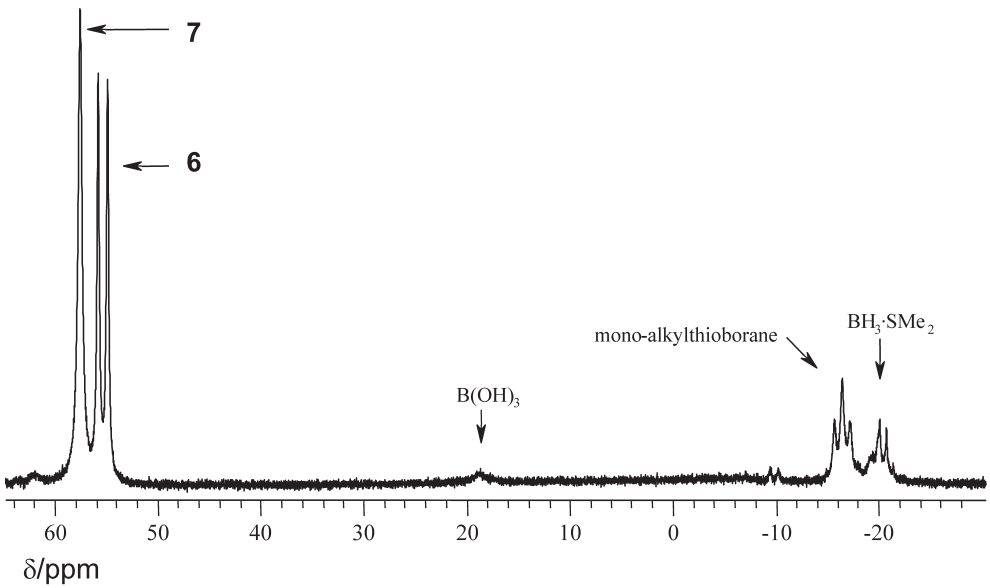
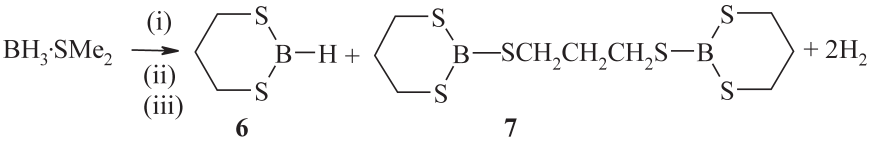
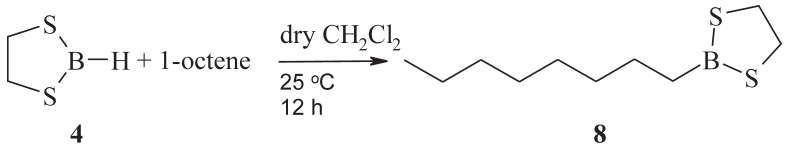


Figure 2 The 160 MHz ^{11}B NMR spectrum showing the fragments obtained in the reaction of propanedithiol with borane-dimethyl sulphide complex.



(i) CH_2Cl_2
(ii) 1,3-propanedithiol, 0 °C, 1 h
(iii) 3 days at 25 °C

Scheme 3



Scheme 4

both hydroborating agents with the intention to justify the mechanism of hydroboration from the values of the entropy of activation $\Delta S^{\neq}$ and the enthalpy of activation $\Delta H^{\neq}$.[14] From the observed rate constants, Eyring plots were computed (Figs. 7A and B).

The temperature dependence study showed that the ring size of the reagent had no effect on the hydroborating activity of the reagent. $\Delta H^{\neq}$ values for both reagents are small and positive, which is indicative of slow, endothermic reactions. $\Delta S^{\neq}$ values obtained for both reagents are large and negative which indicate that hydroboration of 1-octene with 1,3,2-dithiaborolane (**4**) or 1,3,2-dithiaborinane (**6**) proceeds *via* an associative mechanism, in which the hydroborating agent and the olefin unite to form the transition state.

These boranes are indeed slow hydroborating agents. This was evident when compared with $BH_3{\cdot}SMe_2$. They were found to be about 90-fold slower and about six-fold slower than with $BH_3{\cdot}SMe_2$ and with the dialkyl substituted borane dicyclohexylborane, respectively (Table 3). This was due to the electron density donated by the sulphur atoms to the boron atom, which makes the boron atom less electropositive, thus slowing the interaction of the olefinic double bond with the B-H bond.[17]

3. Experimental

3.1. General

All glassware was thoroughly dried overnight in an oven at *ca.* 150 °C. The glassware was further flame-dried by heating with a hot air gun under reduced pressure and allowed to cool under a stream of dry nitrogen, which was passed through a mixture of silica gel and 0.4 nm molecular sieves prior to use. Glass syringes, cannulae and needles were oven-dried and stored in a desiccator (charged with a mixture of silica gel and 0.4 nm molecular sieves) prior to use. Disposable syringes and needles were stored in the desiccator before use, and they were discarded after single use. On assembling the glassware, all joints were wrapped with Teflon® tape, and were subsequently sealed with Parafilm 'M'® to ensure a closed system.

All ^{11}B NMR spectra were recorded on a Varian Unity-Inova 500 MHz NMR spectrometer (Varian, Palo Alto, CA, USA), and were referenced to $BF_3{\cdot}OEt_2$ as an external standard (δ 0.0 ppm) contained within a sealed capillary insert. ^{11}B spectroscopy was utilized in order to identify the compounds as well as to monitor the progress of the reactions. Quartz NMR tubes (5 cm) were used for the ^{11}B NMR spectroscopic experiments and were all oven-dried and flushed with dry nitrogen and sealed with a

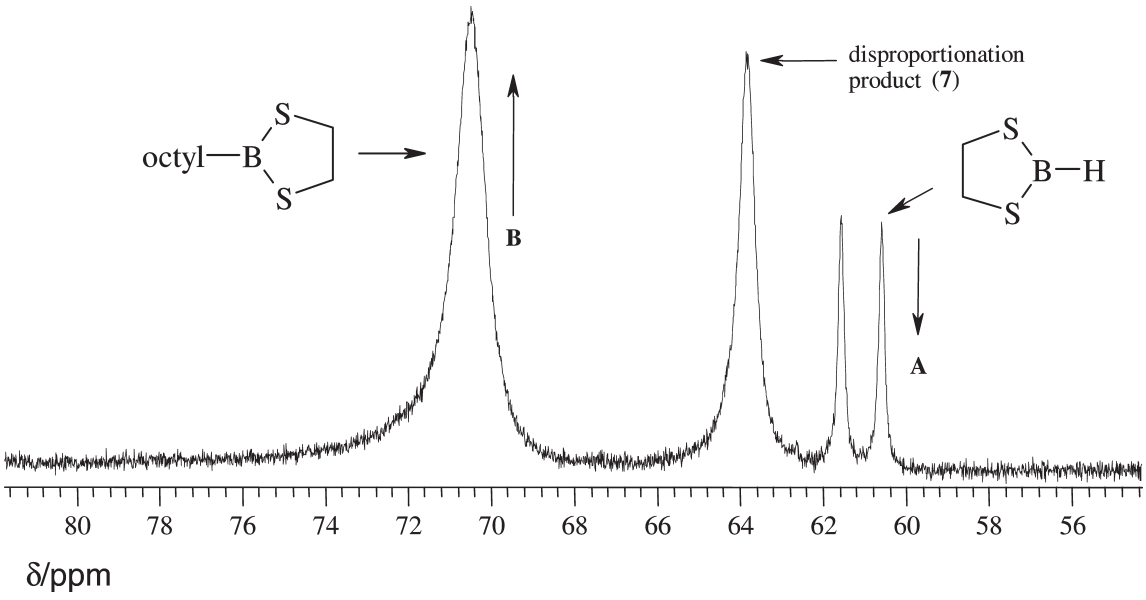


Figure 3 ^{11}B NMR spectrum showing the progress of a typical hydroboration of 1-octene with 1,3,2-dithiaborolane.

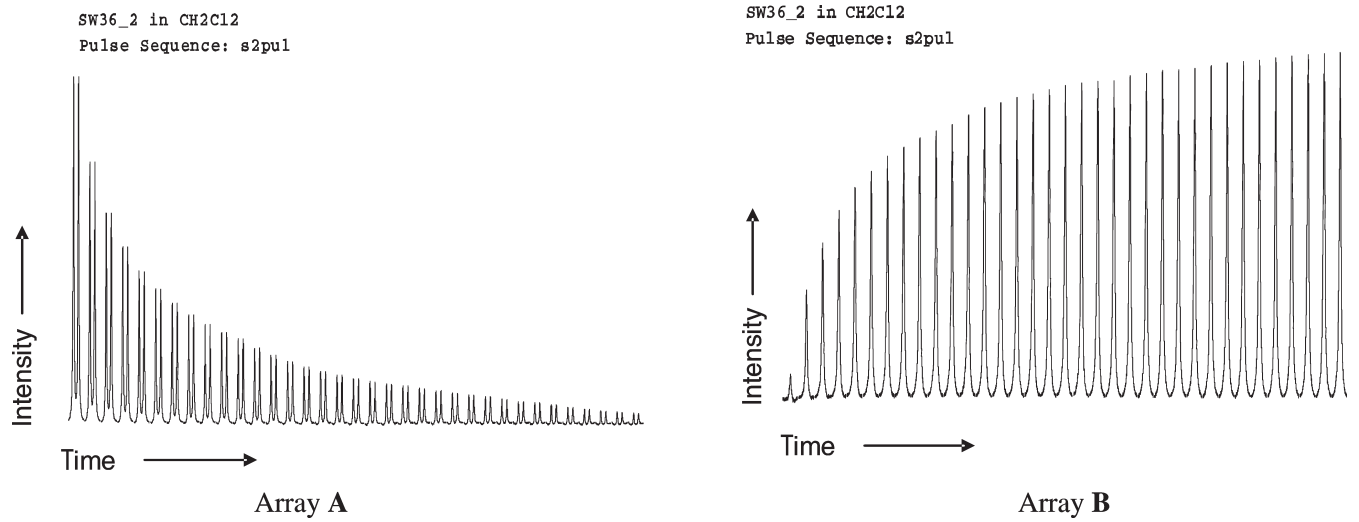


Figure 4 The arrayed reagent depletion (array A) and product formation (array B).[13]

rubber septum prior to injection of the sample or reagents.

All solvents were purified by distillation and dried prior to use.[18] CH_2Cl_2 was distilled over P_2O_5 under dry nitrogen. 1-Octene was distilled over sodium wire in the presence of benzophenone indicator. The solvents were distilled and transferred *via* cannulae to a flame-dried, nitrogen-flushed flask containing 0.4 nm molecular sieves (activated in the furnace at 600 °C and cooled under dry nitrogen) prior to use. 1,2-Ethanedithiol and 1,3-propanedithiol were obtained from Merck-Schuchardt (Hohenbrunn, Germany). The $BH_3{\cdot}SMe_2$ complex in CH_2Cl_2 was obtained from Sigma-Aldrich Co. (Johannesburg, South Africa).

3.2. Preparation of 1,3,2-Dithiaborolane

Following a modification to the procedure described by Egan *et al.*,[6] borane-dimethyl sulphide complex in CH_2Cl_2 (5.0 mL, 5.0 mmol) was transferred into a flame-dried, nitrogen-purged 25 mL two-necked round-bottomed flask. The contents of the flask were subsequently cooled to –84 °C in a liquid nitrogen/ethyl acetate slurry, following which a solution of 1,2-ethanedithiol (471 mg, 5.0 mmol) in CH_2Cl_2 (3 mL) was added dropwise to the stirred flask. The reaction mixture was subsequently stirred for 30 min at –84 °C and allowed to warm up to -60 °C. The flask was then transferred to the cryostat (chiller), and allowed to stir for 14 days at –55 °C under a dry atmosphere of nitrogen to afford a clear liquid comprising a mixture of 1,3,2-dithiaborolane (58 %) ^{11}B NMR (160 MHz, $BF_3{\cdot}OEt_2$): δ = 60.5 ppm (d, J = 156.4 Hz, 1H, B*H*); 2,2′-(ethylenedithio)bis-(1,3,2-dithiaborolane) (40 %) ^{11}B NMR (160 MHz, $BF_3{\cdot}OEt_2$): δ = 64.0 ppm (s); and unreacted $BH_3{\cdot}SMe_2$ (2 %) ^{11}B NMR (160 MHz, $BF_3{\cdot}OEt_2$): δ = –20.5 ppm (q, J = 105.5 Hz, 3H, BH_3).

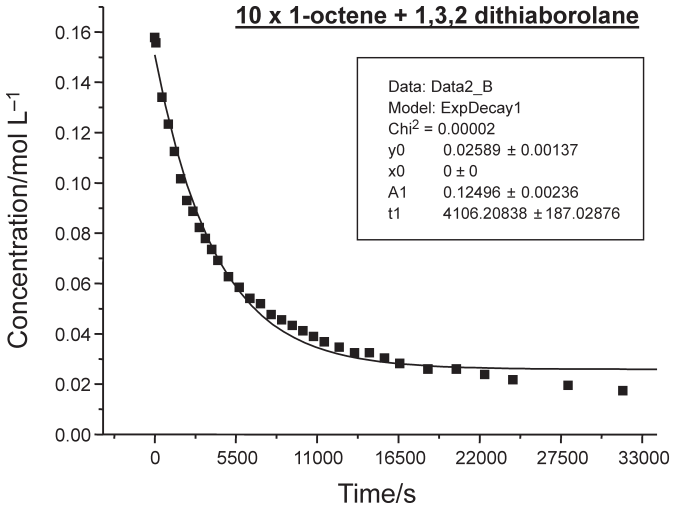
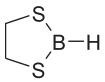
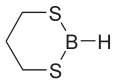


Figure 5 A typical concentration *vs.* time plot, showing fitted experimental data for the hydroboration of 1-octene with 1,3,2-dithiaborolane.

3.3 Preparation of 1,3,2-Dithiaborinane

Borane-dimethyl sulphide complex in CH_2Cl_2 (1.0 mol L^{-1}, 5.0 mL, 5.0 mmol) was stirred at 0 °C under a nitrogen atmosphere. 1,3-Propanedithiol (0.50 mL, 5.0 mmol) was added dropwise over a period of 10 min. The resulting mixture was allowed to stir at room temperature for 7 days to afford a cloudy

Table 2 The observed rate constants for 4 and 6 at each concentration.

			
		4	**6**
Temperature/°C	Concentration factor	$k_{obs}/10^{-4}$ s^{-1}	$k_{obs}/10^{-4}$ s^{-1}
25	10×	2.436	2.645
25	15×	3.855	3.235
25	20×	4.162	3.650
25	25×	4.842	4.435

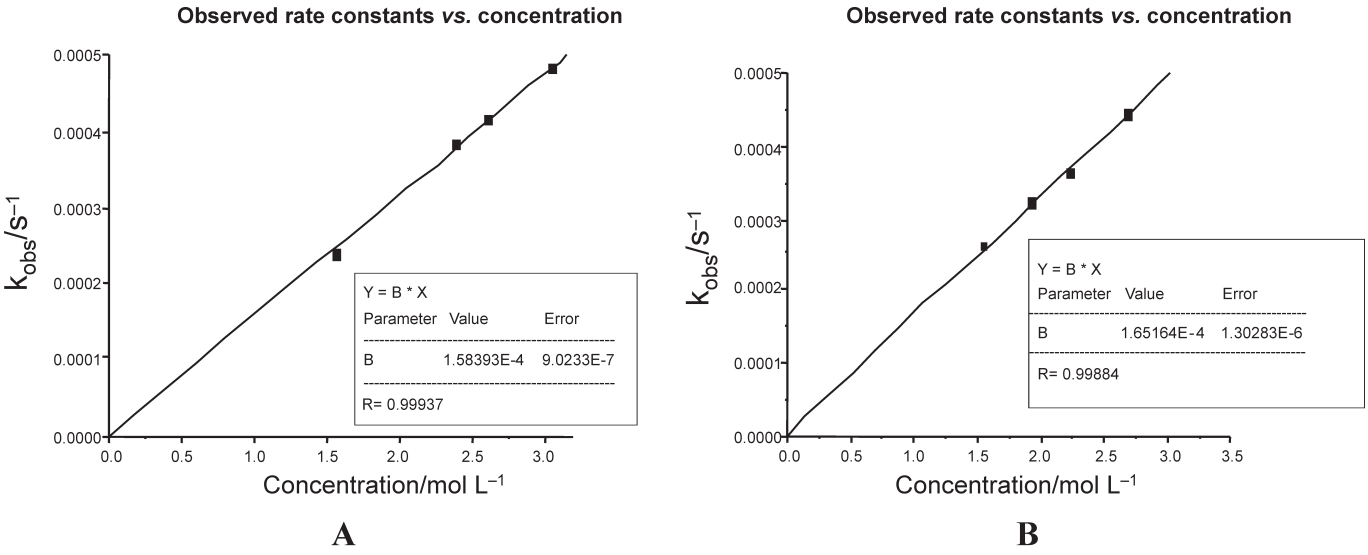


Figure 6 Plots of the observed rate constants *vs.* concentrations. **A** was obtained from the reaction of 1,3,2-dithiaborolane, and **B** from 1,3,2-dithiaborinane with 1-octene. Original acquisition data are available as Supplementary Material.

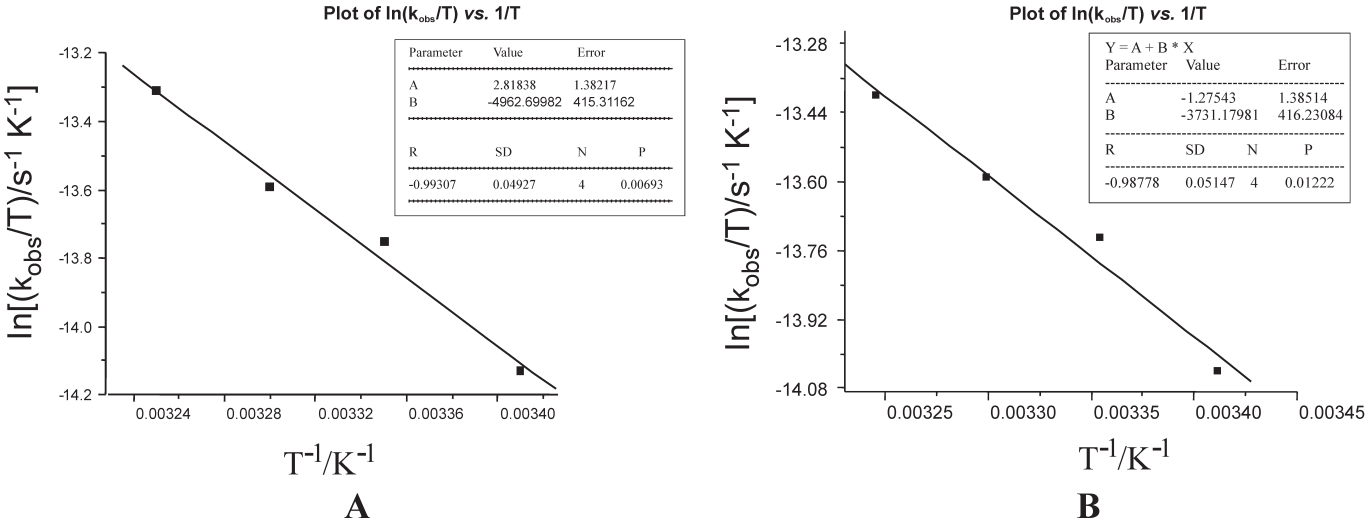


Figure 7 Eyring plots for hydroboration of 1-octene with 1,3,2-dithiaborolane (**A**) and with 1,3,2-dithiaborinane (**B**). Original acquisition data are available as Supplementary Material.

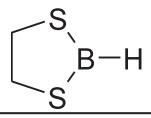
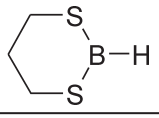
liquid of 1,3,2-dithiaborinane[19] (35 %) ^{11}B NMR (160 MHz, $BF_3{\cdot}OEt_2$): δ = 52.2 ppm (d, J = 145.8 Hz, 1H, B*H*); and 2,2′-(propylenedithio)bis-(1,3,2-dithiaborinane) (55 %) ^{11}B NMR (160 MHz, $BF_3{\cdot}OEt_2$): δ = 56.6 ppm (s); $BH_3{\cdot}SMe_2$ (3 %) ^{11}B NMR (160 MHz, $BF_3{\cdot}OEt_2$): δ = –20.5 ppm (q, J = 105.5 Hz, 3H, BH_3); and $HSCH_2CH_2SBH_2$ (7 %) ^{11}B NMR (160 MHz, $BF_3{\cdot}OEt_2$): δ = –16.9 ppm (t, J = 122.3 Hz, 2H, BH_2).

3.4. Kinetic Studies

In order to determine the rate constants for hydroboration of 1-octene with 1,3,2-dithiaborolane or with 1,3,2-dithiaborinane, the following standard procedure for conducting a concentration dependence study was employed.

To an oven-dried, nitrogen-purged quartz NMR tube 1,3,2-dithiaborolane (0.40 mL, 0.16 mol L^{-1}) was added *via* a

Table 3 Calculated values of the second order rate constant, and enthalpy and entropy of activation for both heterocyclic hydroborating agents.[15]

			CyBH[16] (0 °C)	$BH_3{\cdot}SMe_2$[16] (0 °C)
$k_2/10^{-4}$ L mol^{-1} s^{-1}	1.548 ± 0.009	1.652 ± 0.013	9.7 ± 1.2	140 ± 10
$\Delta H^{\neq}$/kJ mol^{-1}	41.30 ± 3.45	31.02 ± 3.46		
$\Delta S^{\neq}$/J K^{-1} mol^{-1}	–174.45 ± 11.49	174.49 ± 11.52		

syringe. The sample was analyzed to verify that no degradation of the compound had taken place prior to addition of the other reagents. 1-Octene in CH_2Cl_2 (0.40 mL, 10× [1,3,2-dithiaborolane] = 1.6 mol L^{-1}) (a 1.6 mol L^{-1} solution of 1-octene was prepared in a 25 mL volumetric flask, and dichloromethane was used as a solvent for dilutions) was then added to the NMR tube. The tube was then agitated prior to analysis. The time delay taken from injection of the 1-octene to the first scan in the spectrometer was measured by a stopwatch (time delay ranged between 35 and 40 s), and the time delay was used accurately to measure the time intervals between data sets in the NMR spectrometer. The spectrometer program was set to scan the contents of the tube initially very regularly and with time at slower intervals. Initially scans were recorded after every 5 min for the first 50 min, then after every 10 min for a subsequent 100 min, then after every 15 min for 75 min, then every 30 min for 150 min and finally every 1 h for a further 5 h. One hundred and twenty transients were used for each acquisition set, which in turn represented a single data point.

The concentrations of 1-octene were increased from 10-fold to 25-fold that of the hydroborating agent and the above method was repeated for each concentration. The data obtained were fitted using Microcal™ Origin™ 5.0[12] software. The raw data for each concentration dependence experiment are included as Supplementary Material.

In order to determine the thermodynamic parameters $\Delta S^{\neq}$ and $\Delta H^{\neq}$ for the hydroboration of 1-octene with 1,3,2-dithiaborolane or with 1,3,2-dithiaborinane, the following typical procedure for the temperature dependence study was employed.

1,3,2-Dithiaborolane (0.40 mL, 0.16 mol L^{-1}) in CH_2Cl_2 was injected into an oven-dried, nitrogen-purged quartz NMR tube, 1-octene (0.40 mL, 15× [1,3,2-dithiaborolane] = 2.4 mol L^{-1}) (a 2.4 mol L^{-1} solution of 1-octene was prepared in a 25 mL volumetric flask, and dichloromethane was used as a solvent for dilutions) was then added to this solution. The resulting mixture was shaken vigorously, vented and placed in the NMR probe for analysis. Time delay measurements and acquisition time intervals were done in the same manner as discussed above. Hydroboration experiments were conducted at 20 to 35 °C increasing in steps of 5 °C. For each experiment, the concentrations of the hydroborating agent and the olefin were kept constant. The data acquired were fitted with Microcal™ Origin™ 5.0[12] software to yield the activation parameters for each compound towards 1-octene. The raw data for each temperature dependence experiment are included as Supplementary Material.

4. Conclusions

From the above observations, it can be concluded that the reaction of 1,2-ethanedithiol or 1,3-propanedithiol with $BH_3{\cdot}SMe_2$ leads to the formation of both the target borolanes, as well as significant quantities of the disproportionation products. The disubstituted heterocyclic compounds studied in this project were found to exhibit very slow hydroboration properties when compared with $BH_3{\cdot}SMe_2$ or dialkylboranes. In order fully to understand the complexity of the chemistry of these compounds we conducted a follow-up computational study to rationalize our observations.[17]

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13. The percentage integrals of the reactant and product were converted into concentrations and plotted against time in order to obtain the observed rate constants and the second order rate constants.
14. The reaction temperature was varied from 20 to 35 °C. It was unfavourable to go beyond 35 °C due to the low boiling solvent CH_2Cl_2. For each temperature a plot of concentration *vs.* time was plotted.
15. $\Delta H^{\neq}$ = – (slope) × R and $\Delta S^{\neq}$ = (y-intercept – 23.8) × R, where R is the gas constant.
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Supplementary material to:

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1. Hydroboration of 1-octene with 1,3,2-dithiaborolane (4) (concentration dependence study at 25 °C)

Table 1.1 Original data for hydroboration of 10H [1-octene] with 1,3,2-dithiaborolane.

Time/s	Corrected time/s	Product/% integral	Reactant/% integral	Reactant conc./mol L^{-1}	Product conc./mol L^{-1}
0	0	0	73	0.158	0.000
60	92	1	72	0.156	0.002
480	512	6	62	0.134	0.013
900	932	11	57	0.123	0.024
1320	1352	14	52	0.112	0.030
1740	1772	16	47	0.102	0.035
2160	2192	18	43	0.093	0.039
2580	2612	20	41	0.089	0.043
3000	3032	21	38	0.082	0.045
3420	3452	23	36	0.078	0.050
3840	3872	24	34	0.073	0.052
4260	4292	25	32	0.069	0.054
4980	5012	26	29	0.063	0.056
5700	5732	27	27	0.058	0.058
6420	6452	28	25	0.054	0.061
7140	7172	29	24	0.052	0.063
7860	7892	30	22	0.048	0.065
8580	8612	31	21	0.045	0.067
9300	9332	31	20	0.043	0.067
10020	10052	32	19	0.041	0.069
10740	10772	32	18	0.039	0.069
11460	11492	33	17	0.037	0.071
12480	12512	33	16	0.035	0.071
13500	13532	34	15	0.032	0.073
14520	14552	34	15	0.032	0.073
15540	15572	35	14	0.030	0.076
16560	16592	35	13	0.028	0.076
18480	18512	35	12	0.026	0.076
20400	20432	36	12	0.026	0.078
22320	22352	36	11	0.024	0.078
24240	24272	37	10	0.022	0.080
27960	27992	37	9	0.019	0.080
31680	31712	38	8	0.017	0.082

Table 1.2 Original data for hydroboration of 15H [1-octene] with 1,3,2-dithiaborolane.

Time/s	Corrected time/s	Product/% integral	Reactant/% integral	Reactant conc./mol L^{-1}	Product conc./mol L^{-1}
0	0	0	67	0.161	0.000
60	107	2	67	0.161	0.005
480	527	7	56	0.134	0.017
900	947	10	47	0.113	0.024
1320	1367	13	41	0.098	0.031
1740	1787	15	37	0.089	0.036
2160	2207	16	33	0.079	0.038
2580	2627	18	31	0.074	0.043
3000	3047	19	28	0.067	0.046
3420	3467	20	26	0.062	0.048
3840	3887	20	24	0.058	0.048
4260	4307	21	23	0.055	0.050
4980	5027	22	21	0.050	0.053
5700	5747	23	19	0.046	0.055
6420	6467	23	18	0.043	0.055
7140	7187	24	16	0.038	0.058
7860	7907	24	15	0.036	0.058
8580	8627	25	14	0.034	0.060
9300	9347	25	13	0.031	0.060
10020	10067	26	13	0.031	0.062
10740	10787	26	12	0.029	0.062
11460	11507	26	12	0.029	0.062
12480	12527	26	11	0.026	0.062
13500	13547	27	10	0.024	0.065
14520	14567	27	10	0.024	0.065
15540	15587	27	9	0.022	0.065
16560	16607	27	9	0.022	0.065
18480	18527	28	8	0.019	0.067
20400	20447	28	7	0.017	0.067
22320	22367	28	7	0.017	0.067
24240	24287	28	6	0.014	0.067
27960	28007	29	5	0.012	0.070
31680	31727	29	5	0.012	0.070
35400	35447	29	5	0.012	0.070
39120	39167	29	4	0.010	0.070
42840	42887	29	4	0.010	0.070

Table 1.3 Original data for hydroboration of 20H[1-octene] with 1,3,2-dithiaborolane.

Time/s	Corrected time/s	Product/% integral	Reactant/% integral	Reactant conc./mol L^{-1}	Product conc./mol L^{-1}
0	0	0	67	0.131	0.000
60	104	2	65	0.127	0.004
480	524	8	52	0.101	0.016
900	944	12	44	0.086	0.023
1320	1364	14	38	0.074	0.027
1740	1784	16	34	0.066	0.031
2160	2204	18	30	0.059	0.035
2580	2624	19	28	0.055	0.037
3000	3044	20	26	0.051	0.039
3420	3464	21	24	0.047	0.041
3840	3884	22	22	0.043	0.043
4260	4304	22	21	0.041	0.043
4980	5024	23	19	0.037	0.045
5700	5744	24	17	0.033	0.047
6420	6464	25	16	0.031	0.049
7140	7184	25	15	0.029	0.049
7860	7904	26	14	0.027	0.051
8580	8624	26	13	0.025	0.051
9300	9344	26	12	0.023	0.051
10020	10064	27	12	0.023	0.053
10740	10784	27	11	0.021	0.053
11460	11504	27	10	0.020	0.053
12480	12524	28	10	0.020	0.055
13500	13544	28	9	0.018	0.055
14520	14564	28	9	0.018	0.055
15540	15584	28	8	0.016	0.055
16560	16604	28	8	0.016	0.055
18480	18524	29	7	0.014	0.057
20400	20444	29	7	0.014	0.057
22320	22364	29	6	0.012	0.057
24240	24284	29	6	0.012	0.057
26160	26204	30	3	0.006	0.059
29880	29924	30	3	0.006	0.059
33600	33644	30	3	0.006	0.059
37320	37364	30	3	0.006	0.059
41040	41084	31	3	0.006	0.060

Table 1.4 Original data for hydroboration of 25H [1-octene] with 1,3,2-dithiaborolane.

Time/s	Corrected time/s	Product/% integral	Reactant/% integral	Reactant conc./mol L^{-1}	Product conc./mol L^{-1}
0	0	0	57	0.123	0.000
60	103	1	56	0.120	0.002
480	523	6	44	0.095	0.013
900	943	7	37	0.080	0.015
1320	1363	11	32	0.069	0.024
1740	1783	12	28	0.060	0.026
2160	2203	13	25	0.054	0.028
2580	2623	14	23	0.049	0.030
3000	3043	15	21	0.045	0.032
3420	3463	15	19	0.041	0.032
3840	3883	16	18	0.039	0.034
4260	4303	16	17	0.037	0.034
4980	5023	17	15	0.032	0.037
5700	5743	17	14	0.030	0.037
6420	6463	18	13	0.028	0.039
7140	7183	18	12	0.026	0.039
7860	7903	19	11	0.024	0.041
8580	8623	19	10	0.022	0.041
9300	9343	19	10	0.022	0.041
10020	10063	19	9	0.019	0.041
10740	10783	20	9	0.019	0.043
11460	11503	20	8	0.017	0.043
12480	12523	20	8	0.017	0.043
13500	13543	20	7	0.015	0.043
14520	14563	20	7	0.015	0.043
15540	15583	20	7	0.015	0.043
16560	16603	20	6	0.013	0.043
18480	18523	21	6	0.013	0.045
20400	20443	21	5	0.011	0.045
22320	22363	21	5	0.011	0.045
24240	24283	21	5	0.011	0.045
27960	28003	21	4	0.009	0.045
31680	31723	21	4	0.009	0.045
35400	35443	21	3	0.006	0.045
39120	39163	22	3	0.006	0.047
42840	42883	22	3	0.006	0.047

2. Hydroboration of 1-octene with 1,3,2-dithiaborinane (6) (concentration dependence study at 25 °C)

Table 2.1 Original data for hydroboration of 10H [1-octene] with 1,3,2-dithiaborinane.

Time/s	Corrected time/s	Product/% integral	Reactant/% integral	Reactant conc./mol L^{-1}	Product conc./mol L^{-1}
0	0	0	38	0.156	0.000
60	113	1	38	0.156	0.004
480	533	2	37	0.151	0.008
900	953	3	33	0.135	0.012
1320	1373	4	30	0.123	0.016
1740	1793	5	28	0.115	0.020
2160	2213	5	26	0.106	0.020
2580	2633	6	24	0.098	0.025
3000	3053	6	23	0.094	0.025
3420	3473	6	21	0.086	0.025
3840	3893	7	20	0.082	0.029
4260	4313	7	19	0.078	0.029
4980	5033	7	18	0.074	0.029
5700	5753	8	17	0.070	0.033
6420	6473	8	15	0.061	0.033
7140	7193	8	15	0.061	0.033
7860	7913	9	14	0.057	0.037
8580	8633	9	13	0.053	0.037
9300	9353	9	13	0.053	0.037
10020	10073	9	12	0.049	0.037
10740	10793	9	12	0.049	0.037
11460	11513	9	12	0.049	0.037
12480	12533	10	11	0.045	0.041
13500	13553	10	12	0.049	0.041
14520	14573	10	11	0.045	0.041
15540	15593	11	11	0.045	0.045
16560	16613	11	10	0.041	0.045
18480	18533	11	10	0.041	0.045
20400	20453	11	10	0.041	0.045
22320	22373	12	10	0.041	0.049
24240	24293	12	10	0.041	0.049
26160	26213	12	10	0.041	0.049
28080	28133	13	10	0.041	0.053
31800	31853	14	10	0.041	0.057
35520	35573	14	10	0.041	0.057

Table 2.2 Original data for hydroboration of 15H [1-octene] with 1,3,2-dithiaborinane.

Time/s	Corrected time/s	Product/% integral	Reactant/% integral	Reactant conc./mol L^{-1}	Product conc./mol L^{-1}
0	0	0	46	0.130	0.000
60	100	1	43	0.121	0.003
480	520	2	38	0.107	0.006
900	940	3	34	0.096	0.008
1320	1360	3	31	0.087	0.008
1740	1780	4	29	0.082	0.011
2160	2200	4	27	0.076	0.011
2580	2620	5	23	0.065	0.014
3000	3040	5	23	0.065	0.014
3420	3460	6	22	0.062	0.017
3840	3880	6	21	0.059	0.017
4260	4300	6	19	0.054	0.017
4980	5020	7	18	0.051	0.020
5700	5740	7	17	0.048	0.020
6420	6460	7	17	0.048	0.020
7140	7180	8	16	0.045	0.023
7860	7900	8	15	0.042	0.023
8580	8620	8	14	0.039	0.023
9300	9340	8	14	0.039	0.023
10020	10060	8	13	0.037	0.023
10740	10780	9	13	0.037	0.025
11460	11500	9	12	0.034	0.025
12480	12520	9	12	0.034	0.025
13500	13540	9	12	0.034	0.025
14520	14560	9	12	0.034	0.025
15540	15580	9	11	0.031	0.025
16560	16600	10	11	0.031	0.028
18480	18520	11	11	0.031	0.031
20400	20440	11	11	0.031	0.031
22320	22360	11	11	0.031	0.031
24240	24280	12	10	0.028	0.034
26160	26200	12	10	0.028	0.034
28080	28120	13	10	0.028	0.037
31800	31840	13	10	0.028	0.037
35520	35560	14	10	0.028	0.039
39240	39280	15	10	0.028	0.042
42960	43000	15	10	0.028	0.042
46680	46720	16	10	0.028	0.045
50400	50440	17	10	0.028	0.048

Table 2.3 Original data for hydroboration of 20H [1-octene] with 1,3,2-dithiaborinane.

Time/s	Corrected time/s	Product/% integral	Reactant/% integral	Reactant conc./mol L^{-1}	Product conc./mol L^{-1}
0	0	0	41	0.137	0.000
60	100	1	41	0.137	0.003
480	520	2	34	0.114	0.007
900	940	3	31	0.104	0.010
1320	1360	4	28	0.094	0.013
1740	1780	4	25	0.084	0.013
2160	2200	5	23	0.077	0.017
2580	2620	5	22	0.074	0.017
3000	3040	5	21	0.070	0.017
3420	3460	6	19	0.064	0.020
3840	3880	6	18	0.060	0.020
4260	4300	6	18	0.060	0.020
4980	5020	7	16	0.054	0.023
5700	5740	7	15	0.050	0.023
6420	6460	8	14	0.047	0.027
7140	7180	8	13	0.044	0.027
7860	7900	8	13	0.044	0.027
8580	8620	8	12	0.040	0.027
9300	9340	9	12	0.040	0.030
10020	10060	9	11	0.037	0.030
10740	10780	9	11	0.037	0.030
11460	11500	10	11	0.037	0.033
12480	12520	10	10	0.033	0.033
13500	13540	10	10	0.033	0.033
14520	14560	11	10	0.033	0.037

Table 2.4 Original data for hydroboration of 25H [1-octene] with 1,3,2-dithiaborinane.

Time/s	Corrected time/s	Product/% integral	Reactant/% integral	Reactant conc./mol L^{-1}	Product conc./mol L^{-1}
0	0	0	31	0.108	0.000
60	100	1	36	0.108	0.003
480	520	2	31	0.093	0.006
900	940	3	27	0.081	0.009
1320	1360	4	24	0.072	0.012
1740	1780	4	22	0.066	0.012
2160	2200	5	20	0.060	0.015
2580	2620	5	19	0.057	0.015
3000	3040	5	18	0.054	0.015
3420	3460	6	17	0.051	0.018
3840	3880	6	16	0.048	0.018
4260	4300	6	15	0.045	0.018
4980	5020	7	14	0.042	0.021
5700	5740	7	13	0.039	0.021
6420	6460	7	12	0.036	0.021
7140	7180	8	11	0.033	0.024
7860	7900	8	11	0.033	0.024
8580	8620	8	10	0.030	0.024
9300	9340	9	10	0.030	0.027
10020	10060	9	9	0.027	0.027
10740	10780	9	9	0.027	0.027
11460	11500	9	9	0.027	0.027
12480	12520	9	8	0.024	0.027
13500	13540	10	8	0.024	0.030
14520	14560	10	8	0.024	0.030
15540	15580	11	8	0.024	0.033
16560	16600	11	7	0.021	0.033
18480	18520	11	7	0.021	0.033
20400	20440	12	7	0.021	0.036

3. Hydroboration of 15H [1-octene] with 1,3,2-dithiaborolane (4) (temperature dependence study)

Table 3.1 Original data for hydroboration of 1-octene with 1,3,2-dithiaborolane at 20 °C.

Time/s	Corrected time/s	Product/% integral	Reactant/% integral	Reactant conc./mol L^{-1}	Product conc./mol L^{-1}
0	0	0	53	0.124	0.000
60	398	3	51	0.119	0.007
480	818	5	51	0.119	0.012
900	1238	7	47	0.110	0.016
1320	1658	8	43	0.100	0.019
1740	2078	10	40	0.093	0.023
2160	2498	11	38	0.089	0.026
2580	2918	11	35	0.082	0.026
3000	3338	12	33	0.077	0.028
3420	3758	13	32	0.075	0.030
3840	4178	14	30	0.070	0.033
4260	4598	14	28	0.065	0.033
4980	5318	15	27	0.063	0.035
5700	6038	16	25	0.058	0.037
6420	6758	16	23	0.054	0.037
7140	7478	17	22	0.051	0.040
7860	8198	17	21	0.049	0.040
8580	8918	18	19	0.044	0.042
9300	9638	18	19	0.044	0.042
10020	10358	18	18	0.042	0.042
10740	11078	19	17	0.040	0.044
11460	11798	19	16	0.037	0.044
12480	12818	19	15	0.035	0.044
13500	13838	20	15	0.035	0.047
14520	14858	20	14	0.033	0.047
15540	15878	20	13	0.030	0.047
16560	16898	21	13	0.030	0.049
18480	18818	21	12	0.028	0.049
20400	20738	21	11	0.026	0.049
22320	22658	21	10	0.023	0.049
24240	24578	22	10	0.023	0.051
26160	26498	22	9	0.021	0.051
28080	28418	22	8	0.019	0.051
31800	32138	22	8	0.019	0.051

Table 3.2 Original data for hydroboration of 1-octene with 1,3,2-dithiaborolane at 25 °C.

Time/s	Corrected time/s	Product/% integral	Reactant/% integral	Reactant conc./mol L^{-1}	Product conc./mol L^{-1}
0	0	0	67	0.161	0.000
60	107	2	67	0.161	0.005
480	527	7	56	0.134	0.017
900	947	10	47	0.113	0.024
1320	1367	13	41	0.098	0.031
1740	1787	15	37	0.089	0.036
2160	2207	16	33	0.079	0.038
2580	2627	18	31	0.074	0.043
3000	3047	19	28	0.067	0.046
3420	3467	20	26	0.062	0.048
3840	3887	20	24	0.058	0.048
4260	4307	21	23	0.055	0.050
4980	5027	22	21	0.050	0.053
5700	5747	23	19	0.046	0.055
6420	6467	23	18	0.043	0.055
7140	7187	24	16	0.038	0.058
7860	7907	24	15	0.036	0.058
8580	8627	25	14	0.034	0.060
9300	9347	25	13	0.031	0.060
10020	10067	26	13	0.031	0.062
10740	10787	26	12	0.029	0.062
11460	11507	26	12	0.029	0.062
12480	12527	26	11	0.026	0.062
13500	13547	27	10	0.024	0.065
14520	14567	27	10	0.024	0.065
15540	15587	27	9	0.022	0.065
16560	16607	27	9	0.022	0.065
18480	18527	28	8	0.019	0.067
20400	20447	28	7	0.017	0.067
22320	22367	28	7	0.017	0.067
24240	24287	28	6	0.014	0.067
27960	28007	29	5	0.012	0.070
31680	31727	29	5	0.012	0.070
35400	35447	29	5	0.012	0.070
39120	39167	29	4	0.010	0.070
42840	42887	29	4	0.010	0.070

Table 3.3 Original data for hydroboration of 1-octene with 1,3,2-dithiaborolane at 30 °C.

Time/s	Corrected time/s	Product/% integral	Reactant/% integral	Reactant conc./mol L^{-1}	Product conc./mol L^{-1}
0	0	0	62	0.142	0.000
60	102	4	59	0.135	0.009
480	522	11	51	0.117	0.025
900	942	15	43	0.099	0.034
1320	1362	18	38	0.087	0.041
1740	1782	19	34	0.078	0.044
2160	2202	21	31	0.071	0.048
2580	2622	22	29	0.066	0.050
3000	3042	23	27	0.062	0.053
3420	3462	24	25	0.057	0.055
3840	3882	25	24	0.055	0.057
4260	4302	25	23	0.053	0.057
4980	5022	27	20	0.046	0.062
5700	5742	27	19	0.044	0.062
6420	6462	28	18	0.041	0.064
7140	7182	28	17	0.039	0.064
7860	7902	29	15	0.034	0.066
8580	8622	29	15	0.034	0.066
9300	9342	30	14	0.032	0.069
10020	10062	30	13	0.030	0.069
10740	10782	30	13	0.030	0.069
11460	11502	31	12	0.027	0.071
12480	12522	31	12	0.027	0.071
13500	13542	32	11	0.025	0.073
14520	14562	31	11	0.025	0.071
15540	15582	32	10	0.023	0.073
16560	16602	32	9	0.021	0.073
18480	18522	33	9	0.021	0.076
20400	20442	33	8	0.018	0.076
22320	22362	33	8	0.018	0.076
24240	24282	33	7	0.016	0.076
26160	26202	33	7	0.016	0.076
28080	28122	34	7	0.016	0.078
31800	31842	34	6	0.014	0.078
35520	35562	34	6	0.014	0.078
39240	39282	35	5	0.011	0.080
42960	43002	35	5	0.011	0.080
46680	46722	35	5	0.011	0.080
50400	50442	34	4	0.009	0.078

Table 3.4 Original data for hydroboration of 1-octene with 1,3,2-dithiaborolane at 35 °C.

Time/s	Corrected time/s	Product/% integral	Reactant/% integral	Reactant conc./mol L^{-1}	Product conc./mol L^{-1}
0	0	0	56	0.118	0.000
60	95	4	56	0.118	0.008
480	515	13	37	0.078	0.027
900	935	17	28	0.059	0.036
1320	1355	20	23	0.048	0.042
1740	1775	22	20	0.042	0.046
2160	2195	23	18	0.038	0.048
2580	2615	23	16	0.034	0.048
3000	3035	24	15	0.031	0.050
3420	3455	25	13	0.027	0.052
3840	3875	25	12	0.025	0.052
4260	4295	25	12	0.025	0.052
4980	5015	26	11	0.023	0.055
5700	5735	27	10	0.021	0.057
6420	6455	27	9	0.019	0.057
7140	7175	27	8	0.017	0.057
7860	7895	27	8	0.017	0.057
8580	8615	28	7	0.015	0.059
9300	9335	28	7	0.015	0.059
10020	10055	28	7	0.015	0.059
10740	10775	28	7	0.015	0.059
11460	11495	28	6	0.013	0.059
12480	12515	28	6	0.013	0.059
13500	13535	29	6	0.013	0.061
14520	14555	29	6	0.013	0.061
15540	15575	29	5	0.010	0.061
16560	16595	29	5	0.010	0.061
18480	18515	29	5	0.010	0.061
20400	20435	29	4	0.008	0.061
22320	22355	29	4	0.008	0.061
24240	24275	29	4	0.008	0.061
26160	26195	29	4	0.008	0.061
28080	28115	29	4	0.008	0.061

4. Hydroboration of 15H [1-octene] with 1,3,2-dithiaborinane (6) (temperature dependence study)

Table 4.1 Original data for hydroboration of 1-octene with 1,3,2-dithiaborinane at 20 °C.

Time/s	Corrected time/s	Product/% integral	Reactant/% integral	Reactant conc./mol L^{-1}	Product conc./mol L^{-1}
0	0	0	45	0.162	0.000
60	101	1	44	0.158	0.004
480	521	2	40	0.144	0.007
900	941	2	36	0.130	0.007
1320	1361	3	34	0.122	0.011
1740	1781	3	32	0.115	0.011
2160	2201	4	30	0.108	0.014
2580	2621	4	29	0.104	0.014
3000	3041	4	27	0.097	0.014
3420	3461	5	26	0.094	0.018
3840	3881	5	25	0.090	0.018
4260	4301	5	24	0.086	0.018
4980	5021	5	23	0.083	0.018
5700	5741	6	22	0.079	0.022
6420	6461	6	20	0.072	0.022
7140	7181	6	19	0.068	0.022
7860	7901	7	18	0.065	0.025
8580	8621	7	17	0.061	0.025
9300	9341	7	16	0.058	0.025
10020	10061	7	16	0.058	0.025
10740	10781	8	15	0.054	0.029
11460	11501	8	14	0.050	0.029
12480	12521	8	14	0.050	0.029
13500	13541	8	13	0.047	0.029
14520	14561	8	12	0.043	0.029
15540	15581	9	12	0.043	0.032
16560	16601	9	12	0.043	0.032
18480	18521	9	11	0.040	0.032
20400	20441	10	10	0.036	0.036
22320	22361	10	10	0.036	0.036
24240	24281	10	10	0.036	0.036
26160	26201	11	9	0.032	0.040
28080	28121	11	9	0.032	0.040
31800	31841	12	9	0.032	0.043
35520	35561	12	8	0.029	0.043

Table 4.2 Original data for hydroboration of 1-octene with 1,3,2-dithiaborinane 25 °C.

Time/s	Corrected time/s	Product/% integral	Reactant/% integral	Reactant conc./mol L^{-1}	Product conc./mol L^{-1}
0	0	0	46	0.130	0.000
60	100	1	43	0.121	0.003
480	520	2	38	0.107	0.006
900	940	3	34	0.096	0.008
1320	1360	3	31	0.087	0.008
1740	1780	4	29	0.082	0.011
2160	2200	4	27	0.076	0.011
2580	2620	5	23	0.065	0.014
3000	3040	5	23	0.065	0.014
3420	3460	6	22	0.062	0.017
3840	3880	6	21	0.059	0.017
4260	4300	6	19	0.054	0.017
4980	5020	7	18	0.051	0.020
5700	5740	7	17	0.048	0.020
6420	6460	7	17	0.048	0.020
7140	7180	8	16	0.045	0.023
7860	7900	8	15	0.042	0.023
8580	8620	8	14	0.039	0.023
9300	9340	8	14	0.039	0.023
10020	10060	8	13	0.037	0.023
10740	10780	9	13	0.037	0.025
11460	11500	9	12	0.034	0.025
12480	12520	9	12	0.034	0.025
13500	13540	9	12	0.034	0.025
14520	14560	9	12	0.034	0.025
15540	15580	9	11	0.031	0.025
16560	16600	10	11	0.031	0.028
18480	18520	11	11	0.031	0.031
20400	20440	11	11	0.031	0.031
22320	22360	11	11	0.031	0.031
24240	24280	12	10	0.028	0.034
26160	26200	12	10	0.028	0.034
28080	28120	13	10	0.028	0.037
31800	31840	13	10	0.028	0.037
35520	35560	14	10	0.028	0.039
39240	39280	15	10	0.028	0.042
42960	43000	15	10	0.028	0.042
46680	46720	16	10	0.028	0.045
50400	50440	17	10	0.028	0.048

Table 4.3 Original data for hydroboration of 1-octene with 1,3,2-dithiaborinane 30 °C.

Time/s	Corrected time/s	Product/% integral	Reactant/% integral	Reactant conc./mol L^{-1}	Product conc./mol L^{-1}
0	0	0	41	0.142	0.000
60	102	1	44	0.142	0.003
480	522	2	38	0.123	0.006
900	942	3	32	0.103	0.010
1320	1362	4	30	0.097	0.013
1740	1782	4	27	0.087	0.013
2160	2202	5	25	0.081	0.016
2580	2622	5	24	0.078	0.016
3000	3042	6	22	0.071	0.019
3420	3462	6	21	0.068	0.019
3840	3882	6	20	0.065	0.019
4260	4302	7	19	0.061	0.023
4980	5022	7	18	0.058	0.023
5700	5742	8	17	0.055	0.026
6420	6462	8	16	0.052	0.026
7140	7182	8	15	0.048	0.026
7860	7902	9	14	0.045	0.029
8580	8622	9	14	0.045	0.029
9300	9342	9	13	0.042	0.029
10020	10062	10	13	0.042	0.032
10740	10782	10	13	0.042	0.032
11460	11502	10	12	0.039	0.032
12480	12522	11	12	0.039	0.036
13500	13542	11	12	0.039	0.036
14520	14562	11	11	0.036	0.036
15540	15582	12	11	0.036	0.039
16560	16602	12	11	0.036	0.039
18480	18522	13	11	0.036	0.042
20400	20442	14	11	0.036	0.045
22320	22362	14	10	0.032	0.045
24240	24282	15	10	0.032	0.048
26160	26202	16	10	0.032	0.052
28080	28122	16	10	0.032	0.052
31800	31842	18	10	0.032	0.058
35520	35562	19	10	0.032	0.061
39240	39282	21	10	0.032	0.068
42960	43002	22	10	0.032	0.071

Table 4.4 Original data for hydroboration of 1-octene with 1,3,2-dithiaborinane 35 °C.

Time/s	Corrected time/s	Product/% integral	Reactant/% integral	Reactant conc./mol L^{-1}	Product conc./mol L^{-1}
0	0	0	37	0.123	0.000
60	100	0	44	0.123	0.000
480	520	2	36	0.101	0.006
900	940	3	31	0.087	0.008
1320	1360	4	28	0.078	0.011
1740	1780	5	25	0.070	0.014
2160	2200	5	23	0.064	0.014
2580	2620	6	22	0.061	0.017
3000	3040	6	20	0.056	0.017
3420	3460	7	19	0.053	0.020
3840	3880	7	18	0.050	0.020
4260	4300	8	17	0.048	0.022
4980	5020	8	16	0.045	0.022
5700	5740	9	15	0.042	0.025
6420	6460	9	14	0.039	0.025
7140	7180	10	13	0.036	0.028
7860	7900	10	13	0.036	0.028
8580	8620	11	13	0.036	0.031
9300	9340	11	12	0.034	0.031
10020	10060	12	12	0.034	0.034
10740	10780	13	12	0.034	0.036
11460	11500	13	12	0.034	0.036
12480	12520	14	11	0.031	0.039
13500	13540	14	11	0.031	0.039
14520	14560	15	11	0.031	0.042
15540	15580	16	11	0.031	0.045
16560	16600	16	11	0.031	0.045
18480	18520	19	11	0.031	0.053
20400	20440	20	11	0.031	0.056